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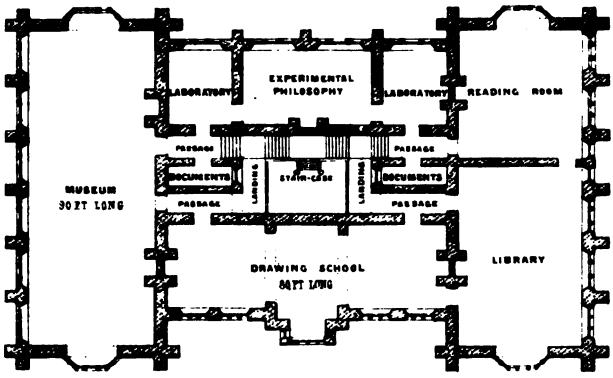

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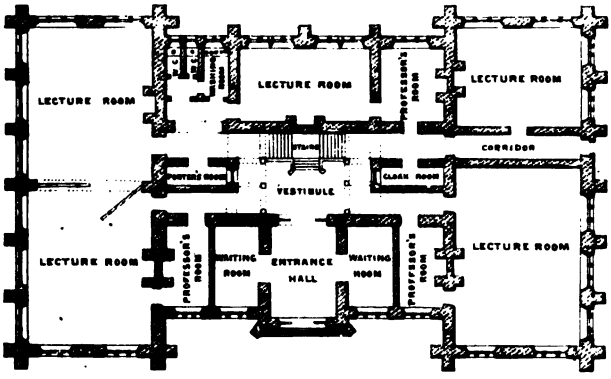

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NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

TRANSACTIONS.

VOL. 4.

1855-6.

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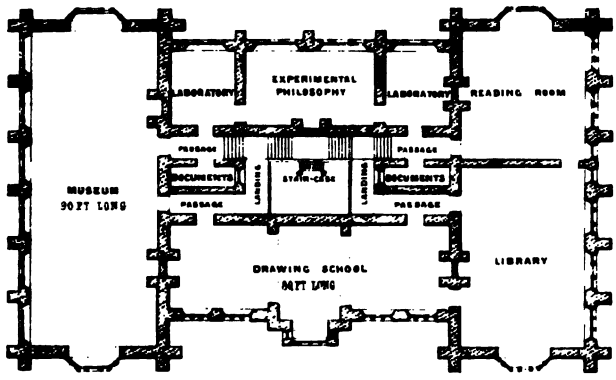

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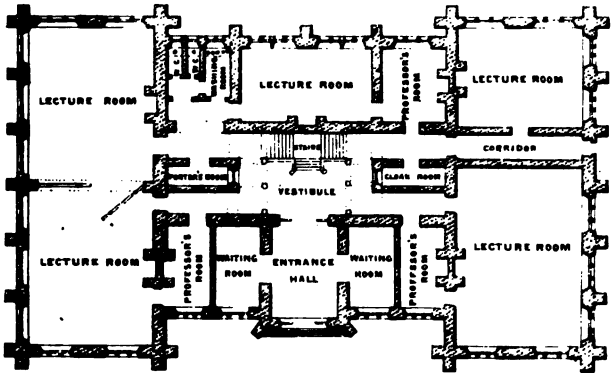

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Finance Committee's Report.

31st JULY, 1856.

TO THE MEMBERS OF THE NORTHERN INSTITUTE OF MINING ENGINEERS.

GENTLEMEN,

We again beg most heartily to congratulate you upon the flourishing state of the funds of the Society, and the general position of the Institute, as shewn by the two accompanying statements of the Treasurer, by which it appears that, at the close of the fourth year of your operations, your cash balance in hand amounts to £540 16s. 10d., the outlay during the year having been £382 13s. 0d., and the income from various sources, added to the balance of the previous year, of £323 17s. 10d., having been £923 9s. 10d.

The annual general statement also shews that the liabilities of the Society amount to £20, and the assets of various kinds to £869 18s. 8d., leaving a balance in favour of the Institute of £849 18s. 8d.

Now that the Stock of Books published by the Society is largely on the increase, we are impressed that it will be highly necessary to open proper stock books, which will shew at a glance the state of the Society's property by an accurate registration of everything as it comes from the press, as well as the disposal of all papers from time to time.

A catalogue of the Books, Maps, &c., possessed by the Institute, should at once be begun, as the prosperous state of your funds ought to encourage a more vigorous action on the part of the Library Committee.

These two matters we submit would be best attended to by a librarian, or person appointed for the purpose, who would give constant attendance at the Rooms on certain days, and afford any information, to the Members requiring it, touching the position of the Society's property.

We should also advise the further consideration of advertizing the Society's Publications, the income from this source having risen from £15 17s. 6d. in 1854-5, to £65 16s. 6d. in 1855-6.

Again, congratulating you upon the prospects of the Institute, and advising vigorous and economical action in the future objects of the Society,

We remain, Gentlemen,

Your obedient servants,

P. S. REID,
EDW. F. BOYD.
W. BARKUS,
CHAS. CARR.

THE TREASURER IN ACCOUNT WITH NORTH OF

1855-6.

1856.	Dr.	£	s.	d.
July 21.—To Balance in Hand from Third Year		323	17	10
" Subscriptions in Arrear from Members at Balancing of 1855 Account, collected during 1856		9	9	0
" Amounts received from Collieries in Arrear at Balancing of 1855, and collected during 1856		51	9	0
" Subscriptions received from Members (elected in 1856, paid for former years)		6	6	0
" Donation per — Wrightson, Esq., in 1854		2	0	0
" Do. per Jos. Davidson, Esq.		1	0	0
" Do. per R. Murray		2	2	0
" Interest on Deposit Receipt in District Bank of £400 since Dec. 15, 1855, up to Aug. 1st, 1856		9	7	6
" Subscriptions from 165 Members to this Date		346	10	0
" Amounts received from the following Collieries to this Date, viz:—				
Seghill	£5 0 0			
Cowpen	5 0 0			
Stella	2 2 0			
Lambton	10 10 0			
Grange	2 2 0			
Kepier Grange	2 2 0			
Haswell	8 8 0			
Black Boy	4 4 0			
Leasingthorne	2 2 0			
Westerton	2 2 0			
Whitworth	2 12 6			
Merrington	2 12 6			
West Hetton and Bowburn, &c.	2 2 0			
Crow Trees and Heugh Hall	2 2 0			
South Kelloe and Coxhoe	2 2 0			
Binchester	2 2 0			
Byers Green	2 2 0			
Hunwick	2 2 0			
Newfield	2 2 0			
Hetton	10 10 0			
North Hetton	6 6 0			
South Hetton	8 8 0			
East Holywell	2 2 0			
Holywell Main	2 2 0			
Barrington	2 2 0			
Thornley	6 6 0			
Trimdon	4 4 0			
		105	11	0
" Amounts received for Sale of Publications:—				
1855, December, per Mr. Reid	22 1 0			
1856, July, per Do.	38 5 6			
1856, July, per Mr. Weale	4 15 0			
1856, July, per Mr. Haun	0 15 0			
		65	16	6
		£923	9	10

ENGLAND INSTITUTE OF MINING ENGINEERS.

1856.	Cr.			£	s.	d.
July 21.—By paid Printing, A. Reid, 1855, March and July		£4	10 0			
" Do.	Do. Do.	16	7 0			
" Do.	Do. July to December	96	12 9			
" Do.	Do. 1856, December to April	132	11 0			
				250	0	9
" paid Postage, Secretary		9	12 8			
" Do.	Treasurer	3	15 8			
" Do.	A. Reid	12	11 0			
				25	19	4
" Paid Circulars, Account Books, Wrappers, &c.				8	9	6
" Paid Sundry Expences on behalf of the Proposed Mining College:—						
500 Copies Prospectus		4	5 0			
Carriage of Do.		0	2 10			
Reducing Plans		3	15 6			
Lithograph of Building		20	16 6			
				28	19	10
" Paid Secretary's Salary, One Year, ending August 1, 1856				25	0	0
" Paid Reporter's Salary, One Year, ending Aug. 1, 1855		12	12 0			
" Paid Reporter's Salary, One Year, ending Aug. 1, 1856		12	12 0			
				25	4	0
" Paid for Geological Maps, Mr. Knipe				4	4	0
" Paid for Sundry Books for Library				13	16	6
" Paid Insurance of Premises in Norwich Union Office, One Year, from August 9, 1855, to and with Sept. 29, 1856				0	19	1
By Balance due from Treasurer				540	16	10
				£923	9	10

GENERAL ANNUAL STATEMENT, AUGUST, 1856.

1856.	Liabilities.	£	s.	d.
July 21.—To Amount of Printer's Bills for Papers in Hands but not yet completed (suppose)		20	0	0
Balance		849	18	8
		£869	18	8

1856.	Assets.	£	s.	d.
July 21.—By Amount of Cash in Hands of Treasurer		540	16	10
" Amount of Books unsold in Mr. Weale's Hand		9	17	0
" Amount of Books unsold belonging to former Years		84	14	0
" Amount of Books unsold belonging to Vol. IV.		110	0	0
" Members Subscriptions Uncollected		58	16	0
" Colliery Do. Do.		36	15	0
" Amount Paid on behalf of the Proposed Mining College, (as above)		28	19	10
		£869	18	8

Patrons.

His Grace the Duke of Northumberland.

The Right Honourable the Earl of Lonsdale.

The Right Honourable the Earl Grey.

The Right Honourable the Earl of Durham.

The Right Honourable Lord Wharncliffe.

The Right Honourable Lord Ravensworth.

The Right Reverend the Lord Bishop of Durham.

The Very Reverend the Dean and Chapter of Durham.

The Venerable Archdeacon Thorpe, the Warden of Durham University.

Wentworth B. Beaumont, Esq.

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T. J. TAYLOR, Earsdon, Northumberland.
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THOMAS DOUBLEDAY.

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Thomas Wynne, Esq., Mining Inspector, Longton, North Staffordshire.
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John Hedley, Esq., Mining Inspector, Derby.
Lionel Brough, Esq., Mining Inspector, South Staffordshire.
Thomas Evans, Esq., Mining Inspector, South Wales.
John Alexander, Esq., Mining Inspector, West of Scotland.
P. Higson, Esq., Mining Inspector, Ridgefield, Lancashire.
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Geheimerbergrath Von Carnell, Berlin.
Mons. Gonot, Mons, Belgium.
Mons. de Boureialle, Paris.

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1 Anderson, W., St. Hilda's Colliery, South Shields.
2 Anderson, C. W., St. Hilda's Colliery, South Shields.
3 Arkley, G. W., Harton Colliery, South Shields.
4 Atkinson, J., Coleford, Gloucester.
5 Adams, W., Ebw Vale Works, Newport, Monmouthshire.
6 Arkless, B., Tantoby, Gateshead.
7 Ashworth, —, Poynton, Cheshire.
8 Armstrong, W., Wingate Grange, Ferryhill.
9 Barrass, T., Little Chilton Colliery.
10 Boyd, E. F., Urpeth, Chester-le-Street.
11 Barkus, W., Low Fell, Gateshead.
12 Barkus, W., Jun., Team Colliery, Gateshead.
13 Barkley, J. T., Constantinople.
14 Berkley, C., Marley Hill Colliery, Gateshead.
15 Bolckow, H. W. F., Middlesbro', near Stockton.
16 Brown, J., Barnsley.
17 Brown, John, Whitwell Colliery, Durham.
18 Bourne, S., Shelton Colliery and Iron Works, near Stoke-on-Trent.
19 Bourne, P., Whitehaven, Cumberland.
20 Burn, D., Busy Cottage Iron Works, Newcastle.
21 Bell, W. H., Sacriston Colliery, Chester-le-Street, Fence Houses.
22 Bell, C. W., 1, Gresham Place, Newcastle.
23 Bell, T., Cassop Colliery, Ferryhill.
24 Bell, J. T. W., Higham Place, Newcastle.
25 Bell, I. L., Washington, Gateshead.
26 Bartholomew, C., Rotherham, Yorkshire.
27 Beacher, E., Thorncliffe and Chapeltown Collieries, Sheffield.
28 Baker, J. P., Chillingworth Colliery, Wolverhampton.
29 Binns, C., Claycross, Derbyshire.

30 Bassett, A. Tredegar Mineral Estate Office, Cardiff.
31 Byram, Benj., Wentworth, Rotherham.
32 Cadwallader, R., Ruabon Colliery, Wrexham.
33 Croudace, J., Washington Colliery, Gateshead.
34 Croudace, C., Washington, Gateshead.
35 Crawford, T., Bowes House, Fence Houses.
36 Crawford, T., Jun., Little Town Colliery, Durham.
37 Crawhall, E. G., Wheldon Bridge, Morpeth.
38 Crone, S. C., Pontop Colliery, Gateshead.
39 Carr, C., Seghill Colliery, Newcastle.
40 Carr, John, Wallsend.
41 Coulson, W., Crossgate Foundry, Durham.
42 Charlton, G., Little Town Colliery, Durham.
43 Carnes, J., West Hetton, Ferry Hill.
44 Cope, J., King Swinford, near Dudley.
45 Cordner, R., Crawley Side, Stanhope, Weardale.
46 Cowen, J., Blaydon Burn, near Newcastle.
47 Coxon, Francis, Lumley Colliery, Fence Houses.
48 Coxon, Samuel Bailey, Usworth Colliery.
49 Crossham, Randall, Shortwood Lodge, Bristol.
50 Dixon, R., Claypath, Durham.
51 Dobson, S., Treforest, Pontypool, Glamorganshire.
52 Douglass, T., Pease's West Collieries, Darlington.
53 Daglish, J., Seaton Colliery, Fence Houses.
54 Day, J. W., Pelaw, Chester-le-Street, Fence Houses.
55 Dees, James, Whitehaven, Cumberland.
56 Dumolo, J., Danton House, Coleshill, Warwickshire.
57 Dunn, Thomas, Richmond Hill, Sheffield.
58 Dunlop, Colon, St. Petersburg, Virginia, U.S.
59 Elliott, G., Houghton-le-Spring, Fence Houses.
60 Elliott, W., Etherley Colliery, by Darlington.
61 Easton, J., Hebburn Colliery, Gateshead.
62 Evans, J., Dowlais Iron Works, Merthyr Tydvil, South Wales.
63 Errington, C. E., Westminster.
64 Embleton, T. W., Middleton Hall, Leeds.
65 Foord, J. B., Secretary-General of Mining Association, 52, Broad-street, London.
66 Forster, J. H., Old Elvet, Durham.
67 Gilroy, G., M.E., Orrell, Wigan, Lancashire.
68 Greenwell, G. C., Radstock Colliery, near Bath.

69 Gray, J., Garesfield Colliery, Gateshead.
70 Green, G. Rainton Colliery, Fence Houses.
71 Greene, W., Jun., Framwellgate Colliery, Durham.
72 Hall, T. Y., Eldon-square, Newcastle.
73 Heckels, R., Bunker's Hill, Fence Houses.
74 Hawthorn, R., Engineer, Newcastle.
75 Hawthorn, W., Engineer, Newcastle.
76 Harrison, T. E., Engineer, Westoe, South Shields.
77 Haggie, P., West-street, Gateshead.
78 Hann, W., Hetton, Fence Houses.
79 Holt, J., Stanton Iron Works, Derby.
80 Hopper, Alex. F., West Auckland Colliery, Durham.
81 Hodgson, Robert, C.E., Whitburn, Monkwearmouth.
82 Hunter, W., Quayside, Newcastle.
83 Hunter, S., Tredegar Iron Works, Newport, Wales.
84 Hynde, W., Ruabon Iron Works, Wrexham.
85 Johnson, R. S., West Hetton, Ferry Hill.
86 Johnson, J. Willington Colliery, Newcastle.
87 Johnson, G., Laffak Colliery, St. Helen's, Lancashire.
88 Joicey, J., Quayside, Newcastle.
89 Joicey, J., Tanfield Lea, Gateshead.
90 Jones, E., Lilleshall Iron Works, Shiffnall, Salop.
91 Jobling, T. W., 13, St. Mary's Terrace, Newcastle.
92 Jeffcock, Parker, Derby.
93 Kimpster, W., Washington Office, Quayside, Newcastle.
94 Laws, J., Blyth, Newcastle.
95 Liddell, J. R., Killingworth Colliery, Newcastle.
96 Liddell, M., Benton Grange, Newcastle.
97 Longridge, J., 17, Fluyder-street, Westminster.
98 Longridge, H. G., Barrington Colliery, Newcastle.
99 Locke, Jos., M.P., Westminster.
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101 Low, Wm., Vron Colliery, Wrexham.
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103 Levick, Frederick, Jun., Cwm Celyn, Blaina and Colebrooke Dale Iron Works, Newport.
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105 Morton, H. T., Lambton Office, Fence Houses.
106 Murray, T., Chester-le-Street, Fence Houses.
107 Murray, Wm., Messrs. Crawhall and Co.'s Ropery, Newcastle.

108 Marley, J., Mining Offices, Darlington.
109 Mundle, W., Ryton, Gateshead.
110 Middleton, J., Davison's Hartley Office, Quayside, Newcastle.
111 Mercer, J., St. Helen's, Lancashire.
112 Mulcaster, H., Blackley Hurst Colliery, St. Helen's.
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115 Potter, E., Cramlington Colliery, Newcastle.
116 Potter, W. A., Mount Osborne Collieries, Barnsley.
117 Pilkington, Wm., St. Helen's, Lancashire.
118 Palmer, A. S., Seaton Burn Colliery, Newcastle.
119 Palmer, C. M., Quayside, Newcastle.
120 Palmer, J. B., Jarrow, South Shields.
121 Philipson, R. H., Cassop Colliery, Durham.
122 Peace, W., Hague Cottage, Wigan, Lancashire.
123 Pickup, Peter, M.E., Barnsley, Lancashire.
124 Plummer, B., Ryhope, Sunderland.
125 Powell, Thos., Newport, Monmouth.
126 Paton, William, Alloa Colliery, Alloa, N.B.
127 Plews, T. R., Newcastle, New South Wales.
128 Richardson, Dr., Portland Place, Newcastle.
129 Robson, J., North Bailey, Durham.
130 Robson, J. G., Old Park Hall, Ferry Hill.
131 Robson, M. B., Field House, Borough Road, Sunderland.
132 Robson, George, Tondû Iron Works, Bridge End, Glagmorganshire.
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134 Rogers, Ebenezer, Abercaw Colliery, Newport.
135 Reed, R. G., Cowpen Colliery, Northumberland.
136 Reid, P. S., Pelton Colliery, Chester-le-Street, Fence Houses.
137 Rutherford, J., South Tyne Colliery, Haltwhistle.
138 Ramsay, J., Walbottle, Newcastle.
139 Ravenshaw, J. H., British Iron Company, South Sea House, London.
140 Southern, G. W., Springwell Colliery, Gateshead.
141 Southern, J. M., Springwell Colliery, Gateshead.
142 Stobart, W., Roker, Sunderland.
143 Stobart, H. S., Etherley, by Darlington.
144 Simpson, R., Ryton, Gateshead.
145 Simpson, L., Medomsley Colliery, Durham.
146 Spencer, W., jun., Whitelee Colliery, Crook, by Darlington.
147 Storey, T., St. Helen's Auckland, Bishop Auckland.

148 Smith, J., Wearmouth Colliery.
149 Smith, F., Bridgewater Canal Office, Manchester.
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151 Southern, Edward, Kibblesworth Colliery, Gateshead.
152 Stephenson, R., M.P., 24, Great George Street, Westminster.
153 Steavenson, A. L., Woodifield Colliery, Crook.
154 Sharp, Henry King, Darlington.
155 Sanderson, R. B., jun., West Jesmond, Newcastle.
156 Shortreed, Thomas, Newbottle Colliery.
157 Sopwith, T., Allenheads, Haydon Bridge.
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159 Stenson, W., Whitwick Colliery, Ashby-de-la-Zouch.
160 Stenson, W., jun., Whitwick Colliery, Ashby-de-la-Zouch.
161 Sinclair, E., Morpeth.
162 Straker, J., South Shields.
163 Sewell, William, Wellington Street, Gateshead.
164 Taylor, H., Earsdon, Northumberland.
165 Taylor, T. J., Earsdon, Northumberland.
166 Taylor, J., Haswell Colliery, Durham.
167 Telford, W., Cramlington, Newcastle.
168 Todd, H. W., Mickley Colliery, Newcastle.
169 Thomas, W., Bogilt, Holywell, Flintshire.
170 Thompson, T. C., Kirkhouse, Brampton, Cumberland..
171 Trotter, J., Newnam, Gloucestershire.
172 Tone, J. F., C. E., Market Street, Newcastle.
173 Vaughan, J., Middlesbro', near Stockton.
174 Ware, W. H., The Ashes, Stanhope, Weardale.
175 Walker, J., Lakelock, Wakefield, Yorkshire.
176 Wales, T., Dowlais Iron Works, Merthyr Tyvdil, Wales.
177 Wood, N., Hetton Hall, Fence Houses.
178 Wood, C. L., Blackboy Colliery, Bishop Auckland.
179 Wood, W., Trimdon Colliery, Hartlepool.
180 Wales, J., Hetton Colliery, Fence Houses.
181 Watson, W., High Bridge, Newcastle.
182 Wilson, J. B., Haydock Rope Works, near Warrington, Lancashire.
183 Wilmer, Frederick, Pensher Colliery, Fence Houses.
184 Woodhouse, J. T., Midland Road, Derby.
185 Walker, T., jun., High Street, Maryport.
186 Webster, Robert Charles, Hoyland Hall, Barnsley.
187 Wilson, Robert, Flimby Colliery, Maryport.

Rules.

1.—That the Members of this Society shall consist of Ordinary Members, Life Members, and Honorary Members.

2.—That the Annual Subscription of each Ordinary Member shall be £2 2s. 0d., payable in advance, and that the same shall be considered as due and payable on the first Saturday of August in each year.

3.—That all persons who shall at one time make a Donation of £20 or upwards, shall be Life Members.

4.—Honorary Members shall be persons who shall have distinguished themselves by their Literary or Scientific attainments, or made important communications to the Society.

5.—That a General Meeting of the Society shall be held on the first Thursday (Friday, for the next Four Months) of every Month, at one o'clock p.m., and the General Meeting in the month of August shall be the Annual Meeting, at which a report of the proceedings, and an abstract of the accounts of the previous year shall be presented by the Council. A Special Meeting of the Society may be called whenever the Council shall think fit, and also on a requisition to the Council signed by ten or more Members.

6.—No alteration shall be made in any of the Laws, Rules, or Regulations of the Society, except at the Annual General Meeting, or at a Special Meeting; and the particulars of every alteration to be then proposed shall be announced at a previous General Meeting, and inserted in its minutes, and shall be exhibited in the Society's meeting-room fourteen days previously to such General Annual or Special Meeting.

7.—Every question which shall come before any Meeting of the Society shall be decided by the votes of the majority of the Ordinary and Life Members then present and voting.

8.—Persons desirous of being admitted into the Society as Ordinary or Life Members, shall be proposed by three Ordinary or Life Members,

or both, at a General Meeting. The proposition shall be in writing, and signed by the proposers, and shall state the name and residence of the individual proposed, whose election shall be ballotted for at the next following General Meeting, and during the interval notice of the proposition shall be exhibited in the Society's room. Every person proposed as an Honorary Member must be recommended by at least five Members of the Society, and elected by ballot at the General Meeting next succeeding. A majority of votes shall determine every election.

9.—The Officers of the Society shall consist of a President, four Vice-Presidents, and twelve Members who shall constitute a Council for the direction and management of the affairs of the Society; and of a Treasurer, and a Secretary; all of whom shall be elected at the Annual Meeting, and shall be re-eligible, with the exception of Four Councillors whose attendances have been fewest. Lists containing the names of all the persons eligible having been sent by the Secretary to the respective Members, at least a month previously to the Annual Meeting;—the election shall take place by written lists, to be delivered by each voter in person to the Chairman, who shall appoint scrutineers of the lists; and the scrutiny shall commence on the conclusion of the other business of the meeting. At meetings of the Council, five shall be a quorum, and the record of the Council's proceedings shall be at all times open to the inspection of the members of the Society.

10.—The Funds of the Society shall be deposited in the hands of the Treasurer, and shall be disbursed by him according to the direction of the Council.

11.—The Council shall have power to decide on the propriety of communicating to the Society any papers which may be received, and they shall be at liberty, when they think it desirable to do so, to direct that any paper read before the Society shall be printed. Intimation shall be given at the close of each General Meeting of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting, and notice thereof shall be affixed in the Society's room ten days previously. The reading of papers shall not be delayed beyond 3 o'clock, and if the election of members or other business should not be sooner dispatched, the President may adjourn such business until after the discussion of the subject for the day.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

GENERAL MEETING, THURSDAY, SEPTEMBER 6, 1855, IN THE ROOMS OF THE INSTITUTE, NEVILLE HALL, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The SECRETARY having read the minutes of the Council,

The PRESIDENT called attention to the resolution, agreed upon at the Council Meeting, relative to the propriety of calling upon the owners of collieries who, as yet, were not upon the subscription list to become subscribers to the Institution. But in order to put the meeting in possession of the circular, he would request Mr. Doubleday, the Secretary, to read it.

The SECRETARY then read the resolution, which was as follows:—

That the draft now read and amended be adopted and printed for distribution, together with a list of the subscribing collieries and the sums given by each: that the subject of the proposed meeting in London to consider of the establishment of the Institution of the National College of Mining and Manufacturing Science be brought before the General Meeting, on Thursday the 6th September.

The PRESIDENT briefly expressed his opinion relative to the subject, and to the propriety of that meeting supporting the views of the Council upon the subject. He might also add that at a meeting of the Council that morning they had passed the following resolution on the question, and which he begged to submit to the meeting. It was as follows:—

That, in pursuance of a resolution passed at the Meeting of Mining Interests in

London, in June last, the following Committee, with power to add to their number, be requested to draw up a Report and Prospectus of the proposed College of Practical Mining and Manufacturing Science, the same to be laid before the November Meeting of the Institute :—Messrs. Nicholas Wood, Hetton Hall; J. T. Woodhouse, Midland Road, Derby; W. Peace, Wigan; C. Binns, Chesterfield; G. C. Greenwell, Bath, Bristol; T. John Taylor, Earsdon; I. Lowthian Bell, Mayor of Newcastle; W. G. Armstrong, Newcastle; H. Lee Pattinson, Newcastle; Thomas Sopwith, Allenheads; R. W. Swinburn, South Shields; Robt. Plummer, Newcastle.

After some remarks, from several members, on the necessity for such an Institution being established, the following resolution was then proposed :—

That the resolution of the Council now read, appointing a committee to draw up a report and prospectus as to the establishment of a College of Mining and Manufacturing Science, in conformity with a former resolution passed by a meeting of Delegates of the Coal and Iron Trades in London, be adopted and confirmed.

The resolution, after a few words from Mr. THOS. J. TAYLOR, was put and carried.

The PRESIDENT then said that as Dr. Richardson had presented the Institute with a copy of his work on "Chemical Technology," he begged to move the thanks of the meeting to Dr. Richardson for his valuable present. Agreed to.

The meeting then proceeded to elect the list of gentlemen proposed at the previous meeting, and, upon a show of hands, they were all elected. Their names are as follows :—William Pilkington, St. Helen's, Lancashire; William Lowes, Vrow Colliery, Wrexham; ——— Murray, Agent to Hawks, Crawshay, & Co., Gateshead; Robert Charles Webster, Hoyland Hall, Barnsley; Benjamin Byram, Wentworth, Rotherham; Thomas Dunn, Jeffcoates, Sheffield; Charles Locke, Rothwell Haigh, Wakefield; T. W. Embleton, Middleton Hall, Leeds; Thomas Powell, Duffryn Colliery, South Wales; Edward Southeran, Kibblesworth, near Gateshead; Randal Cossham, Shortwood Lodge, Bristol.

The PRESIDENT then observed, that he believed there was no paper to be read, but they were in arrears in the discussion of Mr. Atkinson's paper, as well as his own. He, however, thought they ought to proceed with Mr. Atkinson's paper first, as the subject of ventilation was of vast importance, and was the topic of much discussion, elsewhere, at the present time. They had also the printed remarks of Mr. Thos. J. Taylor, which required time for consideration. Looking at the question at issue, it struck him that the first and most important question to determine was the theory of ventilation. As practical men they must first of all come to

a clear understanding on the theory. It was, therefore, necessary to ascertain whether Mr. Atkinson and Mr. Taylor agreed upon this point: for, if not, it would be the duty of members to endeavour to arrive at a correct conclusion on the matter.

Mr. ATKINSON admitted that there were a few difficulties in the paper, but these ought not to deter them from grappling with them. He, therefore, suggested that they should take up the points *seriatim* as they were given in the paper; and also try to ascertain whether there really was any difference between Mr. Taylor and himself.

Mr. THOS. J. TAYLOR was of opinion that from the difficulty and importance of the subject, too little time had been given to enable the members to consider and discuss it properly. It was obvious that unless it was thoroughly considered, the question could not be made useful or intelligible to others.

A brief discussion then ensued respecting the propriety of postponing the discussion of the subject for another meeting, and ultimately a resolution was passed instructing the Secretary to issue a circular for the purpose of acquainting the members of the Institute of the postponement of the discussion of Mr. Atkinson's paper, and calling their attention to the subject.

The meeting then separated.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

GENERAL MEETING, THURSDAY, OCTOBER 4, 1855, IN THE ROOMS OF THE INSTITUTE, NEVILLE HALL, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

Mr. DOUBLEDAY, Secretary, having read the minutes of the Council, and also those connected with the last General Meeting, the following gentlemen were then elected members: J. H. Ravenshaw, South Sea House, London; William Paton, Alloa Colliery, North Britain; E. G. Crawhall, Tredegar Works, Newport; Ebenezer Rogers, Abercarn Colliery, Newport; Alex. F. Hopper, West Auckland.

Mr. T. J. TAYLOR said, that it was highly satisfactory to know that sixteen new members had been elected within the last two months.

The PRESIDENT then drew attention to the discussion upon Mr. Atkinson's Paper, and also the remarks upon it by Mr. Taylor; and observed that he regretted to find that the wish expressed in the circular for a large attendance of members had not been complied with, especially when the importance of the subject about to be discussed was considered. Every member must be sensible that the paper would lead to a thorough investigation of the principles and practice of ventilation, and if so, nothing could be of more importance to the coal mines of this district and of the United Kingdom. He, however, trusted that they would have a better attendance at future meetings; and, now that they had commenced to investigate the subject, they would not abandon it until something satisfactory and conclusive, both as regards the theory and practice of venti-

lation, had been accomplished. In order to facilitate the discussion, he suggested that they should take each Chapter *seriatim* in Mr. Atkinson's Paper, keeping, at the same time, the remarks of Mr. Taylor in view, so that if they found that Mr. Atkinson and Mr. Taylor did not agree they might endeavour to reconcile such differences or suggest further investigations in order to ascertain the correct conclusion.

Mr. T. J. TAYLOR thought that Mr. Atkinson's Paper, being of considerable length, it might be advisable to select portions of it, by way of shortening the proceedings. In writing his remarks he did so, by selecting the principal points of interest in the paper. He observed that Mr. Atkinson had gone into the subject most profoundly, and what he had done was beyond all praise.

Mr. ATKINSON said, that he would like to give every member an opportunity of throwing light upon the subject; and, perhaps, if each head was given out as suggested, any remarks could be made upon them, or if any point was then passed over in silence it might, hereafter, be taken up by some member and be made the subject of a paper.

After a few observations from Mr. HALL and Mr. JAS. LONGRIDGE, it was ultimately agreed to discuss the paper as suggested by the President, viz., Chapter by Chapter.

The PRESIDENT then called attention to No. 1 in Chapter I.; but said that as Mr. Taylor had made no remarks upon it, they would at once proceed to No. 2 in the same Chapter, which that gentleman had noticed. In the first place, however, he begged to ask if Mr. Taylor had any further remarks to offer upon this head of the subject.

Mr. T. J. TAYLOR replied that he would be glad to make one or two observations, the first of which had reference to the comparative effects of temperature and barometric pressure. The rate of the increase of temperature in descending appeared to be about 1° Fahrenheit in every 45 or 46 feet, and it might be regarded as a remarkable circumstance that the increase of temperature thus acquired compensated almost exactly for the increase in barometrical pressure; so that it would appear that the density of air was the same, or very nearly the same, at different depths below the surface. If a principle like this really obtained, the change in the capacity of air for heat as the pressure increased, might possibly account for the difference of temperature in descending, without having recourse to the theory of a central heat. His next remark had relation to the temperature of the current of air entering the mine, requiring some time (as was the fact) before it assumed the ultimate temperature of the mine.

One circumstance, he thought, was peculiarly connected with this result. It was this. As a colder current enters from the surface, its first employment is the evaporation of the water existent in the mine up to the point of saturation, and while thus engaged the extra heat was absorbed. Some time, therefore, must elapse (during the evaporating process), before the final temperature could be attained. Thus, probably, might be partly accounted for the fact that in the return air-courses a higher temperature was found than in the current of air passing in-bye. It was clear that as long as the air was engaged in evaporating water, as described, it could not realise the temperature of the mine.

Mr. ATKINSON begged to say that he thought Mr. Taylor and himself agreed upon the necessity of allowing for changes of density, when they really occur; but it seemed as if these effects, as arising from changes of temperature, at least in some cases, would be counteracted by the opposite changes due to the variation in barometrical pressure, arising from ascents or descents in the mine. In the case, cited by Mr. Taylor, the alteration in density arising from the change in the hygrometrical state of the air would not be more than 1–368th part, and hence could hardly require notice. Calculation shews that if the initial temperature be taken at 51°, then it would require a variation of 1° of temperature for each ascent or descent of 55½ feet, in order that the density might remain unaffected by changes of temperature and barometrical pressure—which is not very far removed from what has been proved by experiments on the subject of internal heat.

The PRESIDENT then observed, that what Mr. Taylor sought to establish was exceedingly important, for it seemed clear by the experiment that the increased temperature, as the air descended, compensated for the increased density, and that the ultimate difference was extremely trifling, being as 101,527 : 101,684, though the difference of depth was 546 feet. This, then, was a most important point, for if they came to the conclusion that at all depths the volume of air was the same, then it would simplify the investigation very much, and would bear materially upon the discussion of the subject in other points of view. In reference to the second part of Mr. Taylor's observations, relative to the temperature of air passing into a mine not giving out heat until it was saturated with moisture as the air descended, that fact was proved very decisively by an experiment made at the Seaton Pit, which was given by him (the President), in the Paper upon "Furnace and Steam Jet Ventilation." In that experiment the pit had not been worked for more than twelve months, and there had never been a furnace within it. There was nothing, therefore, but the natural venti-

lation, so that nothing could disturb the experiment. The shaft was 1560 feet deep, and the difference in the temperature of the air in passing down the shaft from the top to the bottom was only 5·5°, though the depth was 1560 feet. It appeared quite clear that air moving was not followed by an increase of heat to the same extent as air stagnant at increased depths; and they must remember that in mine ventilation investigations they were dealing with a current and not with stagnant air. If they examined this experiment relative to the temperature when the air was stagnant, they would observe the temperature was 62·5° at the bottom of the pit where the air was stagnant, while in the shaft, 120 feet higher, it was only 52°. This experiment was strikingly illustrative of the temperature of air while in a moving state, not accommodating itself rapidly to the temperature due to the depth in deep mines. If, therefore, they found that the air did not give out heat rapidly, and that the expansion due to increased heat counteracted the density due to increased depth, and that, in fact, the bulk of air was nearly the same at all depths, these facts would modify to a great extent the present recognised theories of ventilation.

Mr. M. DUNN thought it very desirable to ascertain the temperature which prevails in the coal strata in metallic mines.

Mr. T. J. TAYLOR replied, that it had been ascertained to a certain extent, and there had been found different temperatures in different species of rocks, as well as in the metallic veins associated with those rocks; the temperature being, as a general rule, higher in the veins than in the rocks.

The PRESIDENT also remarked that some experiments had been made in Cornwall, by Mr. Fox, but they were made in still air.

Mr. J. LONGRIDGE thought what Mr. Taylor meant was this—that if the air acquired the full increase of temperature which was due to the depth, the diminution of density arising therefrom would be exactly compensated by the increased barometrical pressure. It was quite evident that in the case alluded to by the President, the air had not acquired the full increase of temperature due to the depth, inasmuch as such increase would have been 35°, while the President said the increase was only 5½°. The rapid passage of the air through the shafts, in this instance, did not permit it to obtain the full temperature which it would have done had it been stagnant.

Mr. T. J. TAYLOR—The current of air experimented upon might be saturated at 45°, but to saturate it at 60° required, of course, a continuance of the process of evaporation.

The PRESIDENT, in reference to what had fallen from Mr. Longridge, said, that at an increase of 1° for every 45 feet the increase of temperature ought to have been 35°, while by the experiment it was only 5½°.

Mr. ATKINSON—But 1000° of heat might be absorbed in the water evaporated, yet, it being in the latent state, would not affect the thermometer; but, nevertheless, there was one thing he thought militated against Mr. Taylor's idea, although he admitted he was much pleased with it. What he alluded to was, the artesian wells where the medium was stagnant, but the temperature was found to increase as the pressure and the depth increased in descending into the wells, so that the question still arose, what heated the stagnant medium? This no doubt involved the principle of central heat.

Mr. T. J. TAYLOR said that he did not at all intend to repudiate the theory of central heat, but only to mention some circumstances which appeared to cast a suspicion upon the correctness of that theory. He then adverted to what had fallen from Mr. Dunn, and read an extract from "Phillips' Geology" of some experiments made in Cornwall by Mr. FOX, shewing the differences of temperature between the veins and the surrounding rock.

The PRESIDENT said that those observations and experiments bore upon the question of central heat, as the experiments appeared to have been made when the air was comparatively still, and not on the condition of air in motion, as in the case of Seaton Colliery.

Mr. T. J. TAYLOR thought there were opportunities of testing the matter. The air current might be stopped entirely, and its temperature ascertained; in this case no fresh supply of heat would accrue, and if the temperature were found to fall, proof would be thereby furnished that the increased heat was not due to the surrounding strata.

The PRESIDENT was decidedly of opinion that they required more experiments to furnish the requisite data for these disquisitions than they at present possessed. Mr. Taylor, they perceived, rested his inferences of density and the effects of heat in deep mines only upon one experiment; that in itself was not sufficient to justify their coming to a conclusion on the subject. It must be admitted it was most important that all points should be ascertained, beyond any doubt, before they entered further into the investigation. Every one knew that increase of heat expanded air, but according to Mr. Taylor's experiment the density at increased depth counteracted such expansion; it was, therefore, a most important fact to ascertain, and this could only be done by multiplied

experiments. Between Mr. Taylor and Mr. Atkinson there did not seem to be much difference of opinion on this section of the paper, and as the further investigation of the subject would probably give rise to future experiments, they might pass on to Nos. 3 and 4, which Mr. Taylor had classified together in his remarks. The conclusion arrived at by him was that the velocity of air issuing through the aperture was due to that of the *vena contracta*, and not of the orifice.

Mr. T. J. TAYLOR said that Mr. Atkinson had really stated the same thing, so that there was no difference between them.

Mr. J. LONGRIDGE—That was in regard to the quantity of air delivered, but he thought it would be found that Mr. Atkinson did not admit that the velocity was only that due to one-half of the head.

Mr. ATKINSON admitted that it might be less in the orifice than in the *vena contracta*, and that it certainly was so if measured parallel to the axis of the orifice and not in the direction of the converging streams.

Mr. T. J. TAYLOR—The velocity in the orifice was much less than in the *vena contracta*.

Mr. J. LONGRIDGE thought that Mr. Taylor had raised a strong point when he stated that the velocity in the orifice was only that due to one half of the head of motive column.

Mr. T. J. TAYLOR had said that the velocities in the orifices were as the square roots of the heights, and that the velocities in the orifices were less than in the *vena contracta*.

Mr. J. LONGRIDGE doubted such to be the fact.

Mr. T. J. TAYLOR referred Mr. Longridge to Vince, Bernouilli, and others. Did Mr. Longridge agree as to the velocity in the *vena contracta* being equal to that of a body falling through the whole height of the column?

Mr. J. LONGRIDGE.—Yes. But Mr. Taylor spoke of the velocity through the orifice being less.

Mr. T. J. TAYLOR.—That was simply in proportion between the area of the orifice and that of the contracted vein.

Mr. J. LONGRIDGE.—But then, the orifice was larger than the *vena contracta*.

Mr. ATKINSON thought if they took the velocity at right angles to the plane of the orifice, that is to say, parallel to its axis, they would find it less than in the *vena contracta*; but measure it in the direction of the converging streams, and they might find that the theoretical velocity even prevailed in the orifice itself. He, however, was of opinion that for all practical purposes they might take it either way.

Mr. T. J. TAYLOR agreed with the principle as applied to the *vena contracta*, but not to the orifice.

Mr J. LONGRIDGE perceived no difference in the velocity.

Mr. T. J. TAYLOR observed, that the area might be contracted by the aid of a short tube and thus the operation of the *vena contracta* got rid of altogether. In that case the velocity might be equal to that of a body falling through the whole height of column; but the application of such a tube constituted, in fact, a new system.

Mr. ATKINSON considered it was not worth while debating the point any further, as they perfectly agreed upon the quantity discharged, and they were without experimental data to decide by; and as the discharges are the same, viewed in either way, he thought it was scarcely worth further discussion on this occasion.

The PRESIDENT then said they next came to Nos. 5, 6, 7, and 8, still in Chapter I.; Mr. Taylor observing that the density of the air should be taken into consideration. This, however, was much simplified by what had been ascertained by Mr. Taylor of the density being the same at all depths. If the density is meant to be the density of the gas or air pervading the mine, then we have in different cases, different degrees of density, though such density may not be affected by variation in the depths from the surface.

Mr. T. J. TAYLOR—The facts must be taken as they stand.

The PRESIDENT—Then, the density of all the gases, constituting the air of the mine in every case, must be taken into account.

Mr. T. J. TAYLOR—Certainly.

The PRESIDENT then said they had better go on by passing No. 10, upon which little was said; and proceed with No. 11.

Mr. ATKINSON begged to make an observation or two in reply to Mr. Taylor, as he thought Mr. Taylor had misapprehended his meaning. He felt confident, from the nature of Mr. Taylor's remarks, that he must have meant that if the barometer fell half an inch, the density of the air would be reduced at the same time—this he admitted; but the question was this, that as there would then be half an inch less pressure upon the sides of the air-way, would that also reduce the resistance. It certainly would affect the circulation from the changed density of the air, but then, if we suppose the density to be equally increased by a cooling process going on as the barometer fell, the real question returned. It is similar to asking whether water at the bottom of a river 100 fathoms deep had the same

friction as that at the bottom of another river only 10 feet deep? Now, the effect was the same with water in both cases; but it was, perhaps, otherwise with air.

Mr. T. J. TAYLOR replied, by saying that air was compressible, but water, practically, was not. His meaning in the text was, that when the barometer fell, the atmosphere was reduced in weight; and in ventilation, the density of the air constituting the current was reduced in the same proportion, and thus the two circumstances equalised each other.

The PRESIDENT—Passing over No. 12, they came to No. 13, upon the effects of bends.

Mr. T. J. TAYLOR begged to say, that under this head he would take the opportunity of correcting a mistake in the first two lines, by which he was made to express himself in a manner exactly the reverse of what he intended. He could not tell whether the printer or himself was to blame; but at present his remarks read as follows:—"Bends or angles at a distance from the point of greatest pressure have a less effect than those nearer to it;" while the sentence should read thus:—"Bends or angles *near* the point of greatest pressure have a less effect than those *at a distance from it.*"

Mr. ATKINSON thought the information given under this head was limited, yet at the same time valuable, and he had no doubt but that Mr. Taylor's remarks would be appreciated as far as they went.

The PRESIDENT then passed onwards from Chapter II. to Chapter III., because it was devoid of much interest, but in Mr. Taylor's Notes on Chapter III., at No. 19, he pointed out another misprint, which was that the word "expression" ought to be substituted for that of "expansion." With respect to No. 24 "Ventilating Column," it appeared that Mr. Atkinson took simply the common atmospheric air, while Mr. Taylor took all the gases comprising a supposed current of air. There could be no doubt but that the latter was right, but still he questioned the practical utility of such minuteness.

Mr. ATKINSON was sorry to say that he had not had time to check Mr. Taylor's calculations, inasmuch as he must doubt the accuracy of his results; because they appeared to indicate that the density of the upcast column was greater in the case where the mine was supposed to generate carburetted hydrogen gas, than in the case of pure air, and from the mode in which the calculations are given in Mr. Taylor's note, the same error would, he thought, be found to pervade the calculations and results

in the case of carbonic acid gas being given off by the mine; and thus render the apparent discrepancy very much greater than the real one. He might, perhaps, have an opportunity of showing the amount of these errors on some future occasion. While he admitted the principle here aimed at by Mr. Taylor, he thought the errors involved in omitting to allow for these effects would, generally, be of very small amount.

Mr. T. J. TAYLOR considered it unnecessary to comment upon Mr. Atkinson's remarks, as there appeared no difference in principle between that gentleman and himself.

Mr. ATKINSON submitted there was some difference relative to the results in this case, but as his calculations were not completed, he might take a future opportunity of showing that the discrepancies appearing from Mr. Taylor's conclusions were very much too great.

The PRESIDENT called attention to No. 25, and said that he considered the point touched upon in this section most important, as affecting the experiments recently made at Haswell, to ascertain whether Mr. Atkinson was correct or not. The experiment was made by Mr. Taylor with a contracted shaft, and the result apparently showed that the theory was not correct.

Mr. T. J. TAYLOR begged to say that the theory might be correct, as far as it went, but to render it complete there were obviously other circumstances wanting, which must be investigated and established before coming to a correct conclusion. In corroboration of this view of the subject, he would read an account of the experiment recently made at Haswell colliery. Mr. Taylor then read as follows:—

CONTRACTION OF UPCAST SHAFTS.

I.—EXPERIMENT at Haswell Colliery, 28th Sep., 1855. *Effect of Contracting Up-cast Shaft to ¼th of its Sectional Area.*

1.—The quantity of air entering the Haswell Mine is 94,960 cubic feet per minute.

2.—Mean temperature of down-cast pit is 60°.

3.—Mean temperature of up-cast pit is 202°.

4.—Extent of tubbing, cased with bricks, is 75 fathoms (this was done in 1846).

Several experiments were tried in 1839, when the mean temperature of the up-cast pit was only 109°.

Since that period the following changes have been made:—

a.—The furnaces have been more heavily fired.

b.—The under-ground engine was, previous to 1839, worked with only one fire, and very partially: very little work being drawn up the engine bank.

c.—The brick casing has tended to prevent the dissipation of heat.

5.—Coals used for furnace in 24 hours, of peas and duff, ½ each, 122 cwts.

Do. do., underground engine, do., 63 „

Total = 14·39 lbs. per minute.

6.—The mean area of upcast pit is 58 feet.

The upcast pit being contracted so that only 11·859 square feet (·203 of full size) were left for air passage, the current of air in the mine was reduced from 94,960 cubic feet per minute to 67,830 cubic feet per minute, being a ratio of 7 to 5.

	Feet per Second.	Miles per Hour.
The velocity of the air in the upcast pit, considered as unexpanded, is $\frac{94{,}960}{58 \times 60}$	27·2	18·6
Do. Do., as expanded, from 60° to 202°	34·6	23·6
Do. Do., through the contracted space of 11·859 square feet, unexpanded, is $\frac{67{,}830}{11{\cdot}859 \times 60}$	95·3	64·9
Do. Do., through do., expanded, from 60° to 202°	121·4	82·8

During the foregoing experiment the effect of lessened draught on the furnace was scarcely perceptible.

	feet	in.
Height of motive column in air at 202° $\frac{936 \times (202 - 60)}{459 + 60}$	256	0
Height of column due to aperture velocity of 121·4 feet per second $(\frac{1}{8}\ 121{\cdot}4)^2$	231	0
Remainder column, only ..	25·	0

Proportionate column required by calculation to ventilate the mine with a quantity of 67,830 cubic feet per minute,

As $94{,}960^2$: $67{,}830^2$ :: 256 : 130·6 feet.

It appears, therefore, that less than one half (49 per cent.) of the ventilating column is employed in creating the great velocity in the contracted aperture, instead of $\frac{9}{10}$ths of that column being so employed, as the theory under consideration would lead us to expect.

Previous experiments, though not made with such close attention to

details, had prepared me for the foregoing results, the explanation of which is suggested to be as follows.

The ventilating column has really more power than is assigned to it: it is not merely a statical, but also a dynamical agent, acting by its momentum.

The dynamical effect is as the height multiplied by velocity; and by following out this principle the key is obtained to the experimental results—the question really being how much additional momentum is created, or how much is destroyed in each case, such momentum being referred to that of the entire system.

It is assumed that the resistances of fluids are as the squares of their velocities; and there can be no doubt of the fact within at least the range of moderate velocities, because experiments have shewn that it is so. It is the same thing to say that the resistances are as the quantities multiplied by the velocities, for the quantities are as the velocities. But the *power* employed in overcoming the resistance really increases in a greater ratio than the squares of the velocities.

If, for example, we compare a velocity of 24 feet per second with one of 48 feet per second, then the relative resistance is said to be *cæt. par.*, as 24^2 to 48^2, or, as 1 to 4: that is, if in the first case we have a head of 9, we must have in the second a head of 36; and so far the conclusion is correct: but in point of fact the velocity due to the head of 9 is $8 \sqrt{9} = 24$ feet: and the velocity due to one of 36 is $8 \sqrt{36} = 48$ feet.

$$\text{Then } 9 \times 24 = 216$$
$$\text{and } 36 \times 48 = 1728.$$

And thus the longer column, though only four times as high as the other, has really 8 times its dynamical energy. We are right, therefore, in referring to the head or ventilating column, only because that column really possesses (though without our cognizance) the energy in question: and, we may add, requires a corresponding amount of force to maintain it. If, for instance, the air current of a mine be doubled, we require, not four times, but eight times the previous furnace power, or quantity of fuel to realise this new condition: or if machinery in the shape of steam power, or otherwise, be employed, then eight times the former horse-power are also required under similar circumstances: the ratios of increase being, not as the squares, but as the cubes of the velocities.

There are, it should be remembered, three distinct cases of resistance or traction:—

1.—Where the resistances increase as the squares of the velocities. In this case the powers must be *as the cubes of those velocities.*

2.—Where the resistances increase as the velocities simply, the powers must be *as the squares of the velocities.*

3.—Where the resistances are the same at all velocities, the powers must increase *as the velocities.*

The neglect of these distinctions has given rise to a great deal of confusion, as well as of error.

We are not here inquiring into the absolute intensity of the forces under consideration; that intensity, as well as the actual amount of resistance, is to be determined by experiments: but the practical modifications deduced from experiment being *constants*, do not interfere with the results established below as terms of comparison only.

Applying the foregoing remarks to the Haswell experiment, we have the momentum due to the velocity with the shaft free = 94,960 × 1 (a unit representing 34·6 =) 94,960 *a*

And again with shaft contracted 67,830 × 3·50 (representing the ratios of 34·6 to 121·4) ..... 237,405 *b*

Difference..... 142,445

And $\frac{142,445}{94,960}$ = ...Increase..... 1·50005

Then 94,960 × 1 a unit representing the velocity in the mine with shaft uncontracted ..... 94,960 *c*

And 67,830 × ·71 the ratio of the velocities in the mine with shaft contracted.... $\left(\frac{67,830}{94,960}\right)$ = 48,159 *d**

46,801

And $\frac{46,801}{94,960}$ = ... Decrease..... 0·49285

Increase ..... 1·00720

Or state the question as follows:—

1.—Momentum with shaft free, shaft and mine, 94,960 × 1 = 94,960

2.—Momentum with shaft contracted, 67,830 × 3·50 = ... 237,405

Deduct, less momentum in mine in this case .. 46,801

190,604

(94960 − 48159 = 46801, *see calculation*)

Ratios 1 to 2·0072.

* *a* and *c* are alike, because the comparative velocities in the shaft represent also those in the mine, since both increase and decrease in the same proportion.

In like manner *d*, which is a shaft velocity, also represents the mine velocity.

Instead, then, of absorbing $\frac{8}{10}$ths of the motive column by the increased velocity in the contracted space, the actual result is that we have only doubled the resistance, or rather as I have explained it, the momentum of resistance. Now, if this view of the matter be correct, the relative quantities of air in circulation ought to be as $\sqrt{2}$ to $\sqrt{1}$, or as 1·414 to 1.

Let us see if this corresponds with the fact.

As 1·414 : 1 :: 94,960 : 67,060 cubic feet per minute, the ascertained quantity being 67,830 cubic feet per minute; so that the two are so near that practically they may be considered alike.

It is obvious that, on the foregoing principle, the velocity in an aperture may be increased to an extent exceeding that due to the entire height of ventilating column; or in other words, it may be increased as long as the sums of the momenta of the aperture resistance, and of the mine resistance, do not exceed the entire momentum of the ventilating column.

The principle laid down coincides with the fact that the resistances are as the squares of the velocities; for the quantities multiplied by velocities constitute, in effect, a ratio similar to that of the squares of the velocities.

Mr. Atkinson said, that without doubting the correctness of the experiment, yet still he would like to point out others in support of his views. Mr. A. then made reference to some remarks in "Péclet's Traité de la Chaleur." At page 71, 3rd edition, we have a statement by M. Péclet to the effect that "when a chimney is contracted at the top, the velocity of the air in the chimney is diminished, and consequently the friction; thus a large proportion of the motive column is conserved, and therefore the velocity through the contracted orifice ought to be at the same time greater as the orifice becomes less in proportion to the section of the chimney, and the limit which this velocity approximates towards, is that which would prevail in the absence of friction. I have verified these indications of theory in a great number of chimnies, and they perfectly agree with the experiments made by Daubuisson on the escape of cold air produced by a direct pressure."

Mr. Taylor, in answer, begged to draw Mr. Atkinson's attention to a statement by the same author (page 72, 3rd edition), which, he submitted, entirely destroyed the principle of reference to the motive-column as a merely statical agent. That statement was, in substance, as follows; the chimney referred to in the experiment being contracted in its lower portion:—"The velocity due to the height was $10^{m},73$; the observed velocity in the upper part of the chimney was $0^{m},81$, when the contracted

space was $0^m,0006$ in area. Now, as the section of the chimney was $0^m,0314$, the velocity in the orifice was $\frac{0{\cdot}81 \times 0{\cdot}0314}{{\cdot}0006} = 42^m,12$, *a velocity nearly four times as great as that due to the height of motive column.*" The relation of such an experiment showed that they could only escape from the crude condition of the entire subject by experimenting and investigating for themselves.

The PRESIDENT then offered some observations questioning the conclusions arrived at by Mr. Taylor, and especially on his laying too great a stress upon the resistance through the aperture.

Mr. T. J. TAYLOR, however, referred to his document to show that the difference between the President and himself was not material.

The PRESIDENT being satisfied with the explanation, as it nearly coincided with his views upon the point, proceeded to Chapter IV., bearing upon the question between furnace and engine ventilation. He then remarked, that in an early period of the discussion he had incidently mentioned, and it had also been discussed at the Council meeting, that the whole subject, both of the theoretical and practical ventilation of coal mines, was very imperfect. That we were met at almost every step by apparent anomalies between generally received theories and practical results; it was, therefore, most desirable that some practical experiments, on a sufficiently enlarged scale to produce sound and undoubted results, should be undertaken. The Paper of Mr. Atkinson, and the observations by Mr. Taylor thereon, had opened out the subject; and as no subject, to such an Institution as this, could be more important than the question of ventilation, he begged to suggest that a committee should be appointed to suggest and endeavour to have performed such experiments as were necessary to fully elucidate the subject, and as Mr. Atkinson and Mr. Taylor had given the subject, as displayed by their papers, full consideration, he would suggest that those two gentlemen should form part of such committee, and if he could be of any service, in holding as it were a balance between them, he should be most happy to do so. And in order to obtain such assistance in prosecuting the experiments as they might require, they might have a power to increase their number, from time to time, as they might find requisite. Such an investigation, and such a series of experiments he had no doubt would be of essential utility in a mining point of view, and he had no doubt that they would be aided by those members of the Society whose assistance would be most valuable

in performing those experiments; and, likewise, that the lessees of those collieries where experiments were required to be made, would grant permission, and furnish the means for carrying out such experiments.

This suggestion having met with the unanimous approbation of the meeting, the following resolution was passed :—

That the President, Mr. T. J. Taylor, and Mr. J. J. Atkinson be and are hereby appointed a Committee, with power to add to their numbers, to perform experiments in such mines as may be selected by them, for the purpose of procuring information upon the various topics discussed at this day's meeting of the Institute, and particularly in reference to the following leading matters :—

1.—Experiments to determine relative temperatures in the various parts of a mine, accompanied by hygrometrical experiments at the several places of observation.

2.—Shaft-temperatures at intervals of five fathoms, with a view to determine the laws of cooling in shafts.

3.—Experiments as to the effects of contracting the shafts and other portions of mines.

4.—Experiments to determine the comparative facility of ventilating dip and rise workings.

5.—Experiments comparing furnace duty with the duty performed by ventilating machines.

6.—To procure from the chemical members of the Institute, analyses of the air-currents of mines under various circumstances; especially of those discharged from upcast shafts.

The object being that the experiments and results, together with those of any other deemed requisite by the Committee, and arrived at by these means, may be fully reported to the Institute; it being obvious, from to-day's discussion, that some conclusions as to points of great importance, but hitherto involved in much uncertainty, may be arrived at.

The further discussion was then postponed, and the meeting adjourned.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

GENERAL MEETING, THURSDAY, NOVEMBER 1, 1855, IN THE ROOMS OF THE INSTITUTE, NEVILLE HALL, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

Mr. DOUBLEDAY, having read the minutes of the Council as well as those of the last monthly meeting, briefly informed the meeting that according to instructions he had written to Mr. Hutton, and transmitted to him the resolution of the Institute relative to his collection of minerals, but since then he had received no answer.

The meeting next proceeded with the election of Mr. James Dees, of Whitehaven. On a show of hands being taken, the President declared that Mr. Dees was duly elected.

The PRESIDENT then said, that the next business to consider was the Prospectus and Report of the Special Committee as to the Proposed College of Mining and Manufacturing Science. He therefore, begged to call upon Mr. T. J. Taylor to read the document to the meeting.

Mr. T. J. TAYLOR then read as follows :—

PROSPECTUS OF A COLLEGE OF PRACTICAL MINING AND MANUFACTURING SCIENCE,

PROPOSED TO BE ESTABLISHED AT NEWCASTLE-UPON-TYNE.

Names of the Committee appointed (with power to add to their numbers) by a General Meeting of Representatives of the Coal Mining Interests of Great Britain, held in London in July last, and by the Coal Trade and Institute of Mining Engineers of the North of England, for the

proposed establishment, at Newcastle-upon-Tyne, of a College, to be entitled the "British College of Practical Mining and Manufacturing Science":—Nicholas Wood, Hetton Hall, Durham; J. T. Woodhouse, Derby; W. Peace, Wigan; Charles Binns, Chesterfield; G. C. Greenwell, Radstock, Bath; Thomas J. Taylor, Earsdon, Northumberland; I. L. Bell, Mayor of Newcastle; W. G. Armstrong, Jesmond; H. Lee Pattinson, Newcastle; Thos. Sopwith, Allenheads, Northumberland; R. W. Swinburne, South Shields; Robert Plummer, Byker.

It has long been a subject not only of regret but of surprise, that in a country like Great Britain, which for mineral wealth, and the manufactured products of such wealth, is unequalled by any in Europe, a College of Practical Mining Science should still remain *a desideratum*. Nor have inquiries been wanting, from abroad, as to the probability of some such Institution being set on foot, accompanied with intimations that support, as far as a resort to it of pupils may constitute such support, would not be wanting. As a consequence of these first suggestions, the topic has more recently engaged the serious attention of the North of England Institute of Mining Engineers, now consisting of members from all the coal mining districts of England and Wales, by whose request the Council of that body drew up and printed a series of "Suggestions" on this important subject, in which such general details as were deemed requisite, were gone into. These may be not improperly classed under two principal heads. It was first discussed what locality afforded the greatest number of natural facilities for the establishment of such an Institution, and for its being afterwards efficiently conducted. And in the second place were considered, the branches of science directly or collaterally connected with mining generally, which should be taught by such an Institution. The result of the first inquiry was that, after natural advantages, central position, and local manufacturing and trading pursuits were considered and compared with those of other mining localities, Newcastle-upon-Tyne was decided upon as being, beyond question, possessed of the greatest number of these advantages, and, consequently, a site the most advisable for such a foundation. The result of the second discussion was a programme of the education peculiar to such an establishment, embracing eight distinct branches of teaching, which were deemed to be desirable for the purposes of practical engineering, as applied to mines, whether of lead, copper, tin, iron, or coal, as well as for those branches of science which bear upon the most important manufacturing processes.

In addition to these more general considerations, others of minor character were gone into and stated; and the whole being printed as a pamphlet, was circulated amongst gentlemen engaged in the coal trade and in iron mining pursuits, so extensively carried on in Northumberland and Durham, and amongst those engaged in the manufactures of which coal, iron, lead, and their products white lead, litharge, colours, coke, artificial alkalies, machinery, &c., &c., are a constituent portion.

The wide distribution of this tract by the Council of the North of England Mining Institute gave the question a practical bearing and consequence, which it had not hitherto nor before attained, and the wished for result of thus directing attention to the subject, was the adoption of a resolution by the Delegates of the British coal and iron mining interests assembled in London, in May, 1854, to the following purport:—

That this meeting is of opinion that it would be of essential service in the future management of mines, and consequently have a tendency to the prevention of accidents, if a central Mining School, or College, of a practical nature, were established in some convenient and suitable colliery district, with branches therefrom and connected therewith, for the education of mining engineers, or other officers and subordinate persons, to be entrusted with the management and conduct of the mines of this country. And that the Parliamentary Committee, now sitting on Accidents in Mines, be solicited to take this subject into their serious consideration, with a view of recommending the Government to afford such aid as they may deem advisable and requisite to establish an institution so necessary and laudable.

In consequence of this suggestion the Committee reported that "they would urge upon Government to foster by grant in aid, the establishment and maintenance of Mining Schools in the large Mining Districts throughout the Country."

This resolution having been widely promulgated, together with the printed suggestions of the Council of the North of England Institute of Mining Engineers, led to a further discussion, by the delegates assembled in London, during the following year, by whom the resolution was confirmed, and the site of Newcastle-upon-Tyne named as the most convenient for a foundation of this peculiar nature.

Such is the shape which the question of a central British College of Practical Mining Science has now assumed, and, in compliance with the instructions of their constituents, your Committee now venture to state in detail such further considerations as seem to arise out of the circumstances.

Before proceeding to perform this duty, however, it is necessary to state that, as far as this district is concerned, the proposal to found such

a College has already received the sanction of our great mining interest, the Coal Trade.

On the 6th February of this year, the subject was brought before a General Meeting of the Coal-owners of the Counties of Northumberland and Durham, as a portion of the Annual Report of the General Committee of the Trade. The opinions of the Committee were expressed in the following paragraph :—

Your Committee now turn, not without gratification, to another topic, which is unquestionably indicative of the advancing state of the trade, this is the Report of the Council of 'The North of England Institute of Mining Engineers,' on the proposed establishment of a College of Practical Mining Science at Newcastle-upon-Tyne, laid before your Committee by that body, and now in the hands of the members of the trade universally. Presuming that the details of this report are known to all present, the Committee can only proceed to impress upon the lessees and lessors also of collieries and mines, the vital importance of giving the proposals, embodied in the document referred to, their best and most favourable consideration. The period has hardly arrived for the Committee to venture a conclusive opinion as to the most eligible mode of raising such funds as may be requisite to erect such an institution on a highly respectable and thoroughly independent foundation, and to secure its permanent utility when so established; but they may express their belief that such support cannot be safely left to spontaneous liberality. It appears to them, on the contrary, desirable that the wealthy and influential interests engaged in the great trades of raising, manipulating, and shipping the coal, iron, and lead, with which these counties abound, in all the forms and combinations which these materials are capable of entering into, or assuming, or are found, together with such friends to the undertaking out of these districts as may be disposed to aid it, should join in procuring either a Charter or an Act of Parliament, of such a nature as would, for a given number of years, secure the accruement of the funds necessary to give prosperity to the institution, as well as such permanent pecuniary aids as might in future time be essential to the entire utility and vitality of such an establishment. Your Committee, on the present occasion, deem it their duty to express, generally, their warm approbation of the scheme, as sketched in the Report of the Council of Mining Engineers, and their hope that the great body of the coal trade will add their efforts to promote, by a resolution this day, this great undertaking, for which all opinions seem to concur in pronouncing this locality to be peculiarly adapted by circumstances as well as by nature, but which is, in itself, of national rather than local importance.

The result of this communication and recommendation of the General Committee to the Coal Trade, was the adoption, by the meeting, of the following resolution, passed confirmatory of the convictions of the Committee, and impressing upon the Coal Trade, as a body, the good policy of encouraging the foundation of such a College of Practical Mining and Manufacturing Science :—

That the Meeting concurs in the Report of the Mining Institute, and in the opinion of the Committee of the Trade, that it is highly desirable to establish a College for the

Advancement of Practical Mining and Manufacturing Science at Newcastle, a locality so well adapted for that purpose, and strongly recommend the Trade to support the same; and the Meeting is further of opinion that the Lessors of Mines and the Mining Interests generally of this and other portions of the Kingdom, as well as the Government, should be applied to for support to such Institution, the object of which appears to the Meeting one of not merely local but of national importance, bearing as it does upon increased skill and economy in production, and also upon the due security of life and property.

Thus, it may now be, without impropriety, assumed that the subject has received the consideration and sanction of the coal and other mining interests of the kingdom at large, as well as of the Northumberland and Durham district, and of those gentlemen in other mining localities who are members of this Institute, and by their acquirements and pursuits qualified to give active and efficient aid to an undertaking of this nature.

The Committee would now draw attention to the detailed plan of the College proposed, which seems to them to embrace the requisites calculated to make it efficient as a Central School of the Practical Science of Mining in all its branches, as carried on in European Countries.

It has been already stated that the science of practical mining seems naturally to divide itself into eight departments, which are as follows:—

1. Mathematics;
2. Natural Philosophy and Mechanics;
3. Mechanics, in their Application;
4. Plan Drawing, Surveying, Levelling, Machine Drawing;
5. Mine Surveying;
6. Chemistry, Practical and Theoretical;
7. Mineralogy and Geology;
8. The Working of Mines.

These branches, or departments, appear to the Council to include everything directly or indirectly requisite to mining engineering, in the most extended meaning of the term. It does not, however, appear to the Council to follow, necessarily, that each of these branches would require the services of a separate Professor: Mechanics, both in theory and application, together with natural philosophy, as far as it is connected with mining, might be taught by one Professor. Plan drawing, levelling, machine drawing, and mine surveying, might also be comprised in one department and taught by one competent person.

There remain,

Chemistry	1	Professor.
Mathematics	1	Do.
Mineralogy and Geology, and Working of Mines	1	Do.

A competent knowledge of the subjects taught by these five Professors may be acquired by a diligent pupil in two yearly courses, extending over six or eight months in each year, divided into two or more terms; but it may be desirable to adopt a course of instruction for a period of three years, and also to make arrangements for admitting managers of mines, or pupils of mining engineers or mechanics, wishing to avail themselves of the College for a limited number of terms or classes in each year.

The College might also be open to young men, who may become students of, or who may wish to attend a course of lectures on any particular branch of science.

The College ought to maintain a scientific, combined with a thoroughly practical character. The situation of Newcastle, in the midst of the most extensive and difficult mining concerns in the kingdom, peculiarly adapts it as the situation, above all others, where sound practical knowledge can be obtained; an advantage, the absence of which has been severely felt by similar institutions on the Continent, rendering the course of instruction at these universities more of a theoretical than a practical nature, though the acquisition of knowledge is duly appreciated and adopted, wherever it is possible to engraft it upon the usual course.

With a view to bear out the practical character of the institution, it is proposed that pupils shall not be eligible for the honours it may have to bestow, unless they have had two years actual experience in the mines or manufactories. This rule, however, is not meant to exclude persons who may wish to attend particular courses of lectures without laying claim to the privileges the College can confer. Foreign students will be admitted on certificates that the rules for admission have been complied with, whether in their own country or elsewhere. The teachers or professors and pupils, are proposed to have access to the mines and to the manufactories under arrangement with the owners; and to make periodical tours into the mining districts, to study the geological features of the coal and other formations, and their associated rocks and minerals.

It is proposed that the students be examined annually on their progress in practical and scientific knowledge, in such manner and by such persons as shall be prescribed by the rules of the Institution, or which shall, from time to time, be laid down and appointed by the Governors; and certificates of progress and standing shall be awarded to the pupils who shall pass the required examination, with certificates of honours or proficiency, as may be determined by the Governors, and embodied in the constitution of the establishment. The question of honours, by

degrees or otherwise, to be conferred by the College, involves a variety of considerations, and may properly, in the estimation of the Council, be left to the arrangement and decision of the governing body.

The fee for admission is proposed to be *twenty pounds* in one payment in advance; or two annual payments of *twelve pounds* each, for the whole course. Separate arrangements to be made for fees of attendance on particular classes; and young men engaged as practical miners to be admitted at such reduced fees as may be determined by the governing body. Donors of *one hundred pounds* to be entitled to nominate a pupil on payment of half the usual fees; and for every like sum, as many pupils on the same terms.

All matters connected with the funds, and with the district and central establishment, to be under the management and supervision of a Board of Governors.

Though the Institution is intended to be self-sustaining, its first establishment, with a proper building, class rooms, and apparatus, will involve the expenditure of a considerable sum. To the lessors and lessees of mines, as most interested in the subject, the Council naturally look for the most efficient support. The Corporations of Newcastle and of the other large towns in the district may be also expected substantially to aid the project. Neither can the Committee forbear from noticing that there are surplus funds arising out of the mines in the diocese of Durham, the application of a portion of which to the protection of life and property in those mines would surely be a very suitable appropriation.

The annual expenditure of such an Institution, including the salaried officers, such as Registrar, Curator, Door-keeper, &c., &c., also moderate endowments of the Professorships, but exclusive of interest of money sunk in building, would require a revenue say of £3,000.

With regard to the building requisite, the Council may refer to the elevation and ground-plan furnished by Mr. Archibald Dunn, and constituting the frontispiece to this prospectus. The cost of the building is estimated at £16,000. The entire capital required to be raised, including the purchase of suitable apparatus and endowments for Professors, is estimated at £35,000. Two obvious methods suggest themselves as means of raising and securing the funds necessary for the proposed undertaking. The first of these is to obtain an Act of Parliament, with the assent of all interested, for the levy of a small *per centage*, payable to trustees for this specific purpose, and calculated upon the values or tonnage of the coals, iron, lead, copper, and tin, raised by those who are parties

to the Act; The second is a voluntary subscription, covenanted for in a trust-deed of mutual agreement, to be signed by the parties, and having the force of a legal agreement or bond, vesting the property in trustees. At this stage of the undertaking the Council do not deem it necessary to do more than give a general idea of the trifling amount of *per centage* upon the products enumerated, amply sufficient to raise the sum required; whether this district alone be considered, or the mining interests of the other mining localities of Great Britain be included.

In the valuable Statistical Returns, compiled by Robt. Hunt, Esq., Keeper of Mining Records, and by him presented to the Library of the North of England Institute of Mining Engineers, are given the totals as well as the detailed particulars of all the coal, iron, tin, lead, copper, and silver raised, or smelted, in the United Kingdom, together with values; the quantities raised or smelted in the several districts being distinguished and stated, together with the greater totals, as follows:—

COAL.

	TONS.	VALUE.	
England—Northumberland and Durham	15,420,615		
„ Cumberland	887,000		
„ Yorkshire	7,260,500		
„ Derbyshire	2,406,696		
„ Nottinghamshire	813,474		
„ Warwickshire	255,000		
„ Leicestershire	439,000		
„ Staffordshire and Worcestershire	7,500,000		
„ Lancashire	9,080,500		
„ Cheshire	786,500		
„ Shropshire	1,080,000		
„ Gloucester, Somerset, and Devon	1,492,366		
North Wales	1,143,000		
South Wales	8,500,000		
Scotland	7,448,000		
Ireland	148,750		
	64,661,401	£14,975,000	(at Pits.)
Tin	5,763	690,000	
Copper	13,042	1,229,807	
Lead	64,005	1,472,115	
Silver, 700,000 ounces		192,500	
Iron, (pig)	3,069,838	9,500,000	
Zinc		16,500	
Arsenic, sulphur ores, and sundry minerals		500,000	
		£28,575,922	

On coal only, therefore, a tonnage of so small an amount as the 1-90th of a penny per ton (a penny for every 90 tons), would raise a sum of £3,000 a year. Or a payment of twopence-halfpenny in every one hundred pounds value of the mineral produce of the United Kingdom, would raise the like annual amount of £3,000.

But whilst the contribution thus required to raise the requisite funds is of so trifling an amount that it would entail upon a colliery, vending 6,000 tons yearly, a payment of only £2 15s. per annum; yet, considering the difficulty of collection over so wide an area, the possible opposition of particular coal owners to a parliamentary tax, and having regard especially to the circumstance, that the proposed Institution may be expected, not unreasonably, to be self-sustaining, the Committee lean to the opinion, relying upon the great individual interests connected with the mineral produce of the kingdom, that the plan of a subscription would be the preferable one.

To this course they do not yet, however, pledge themselves. Indeed their position is such that they must first feel their way and permit themselves to be governed in a great measure, by future events: expressing, at the same time, their conviction that a project, having for its purpose the establishment of an Institution so directly bearing upon economy in production and upon the preservation of life, cannot be, as it ought not to be, otherwise than eminently successful.

The PRESIDENT, at the termination of the paper, observed that having just heard it read, it was for them to judge whether they should adopt it or not; if they agreed to adopt it the Committee were still willing to receive any recommendation from any member likely to promote the general object in view.

Mr. M. DUNN thought they could come to no decision on the subject without an Act of Parliament.

Mr. TAYLOR replied, that it would be a very difficult thing to get an Act of Parliament upon which the coal owners of England and Wales would all agree.

Mr. DUNN—But they could not secure a revenue without an Act of Parliament.

Mr. TAYLOR—The numerous pupils would be a source of revenue without it.

The PRESIDENT observed, that as a beginning they only required

£35,000, and he thought it indeed a very extraordinary thing that such a sum could not be raised among the lessors and lessees of collieries, aided by the Corporation of that town and the manufacturing interests in the vicinity, and the other parties interested in the College belonging different parts of the kingdom.

Mr. DUNN—If they agreed upon the voluntary principle, would it not be proper to lay down some rule for receiving subscriptions.

Mr. TAYLOR objected to such a course being adopted, as he felt confident that several parties connected with the Coal Trade would come forward handsomely and subscribe large sums without any dictation as to what they should subscribe.

The PRESIDENT coincided with Mr. Taylor, as he thought it not desirable to lay down any scale of subscription. If parties agreed to a scale beforehand that would alter the matter. At present, after passing the report before them, they might propose a resolution recommending that efforts be made to obtain subscriptions; and if, in a short time, after appealing to certain noblemen and gentleman in the trade they realized £10,000 or more, that in itself would be a good beginning, and set an example to other parties to come forward. The necessity and importance of the College was such, that he could scarcely doubt the most successful results from a well organized plan for securing subscriptions. With their permission he therefore begged to submit the following resolution to their notice:—

That the prospectus read be approved of and adopted, and that it be printed and circulated; and also that a committee be requested to take such steps as may be requisite to procure subscriptions for the establishment and support of the proposed College.

The PRESIDENT then put the above motion, which was carried unanimously; after which he said that the only subject for discussion seemed the resuming of Mr. Atkinson's Paper.

Mr. T. J. TAYLOR, however, begged to say that he understood that the discussion was adjourned at the last meeting, until the committee appointed should make certain experiments, the result of which is to be reported hereafter. Already some heads of experiments had been furnished, which, perhaps, the Secretary would be so good as read.

Mr. DOUBLEDAY then read the heads of the experiments, which will be found at page 21.

The PRESIDENT remarked that the next paper in order of discussion

was his own upon the conveyance of coals underground, and he should be glad to hear any observations upon it, as it was a subject of great importance in an economical point of view.

A long and desultory conversation ensued upon the subject; after which it was ultimately agreed to postpone the discussion of the subject until the next meeting, it being argued that as the subject was of such great importance, it required more time for consideration.

The meeting then broke up.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

GENERAL MEETING, THURSDAY, DECEMBER 6, 1855, IN THE ROOMS OF THE INSTITUTE, NEVILLE HALL, NEWCASTLE-UPON-TYNE.

T. J. TAYLOR, ESQ., ONE OF THE VICE-PRESIDENTS, IN THE CHAIR.

The CHAIRMAN, on taking his seat, said that he was sorry to say that their respected President had been obliged to leave them that day, in order to enable him to meet his family. The presence of Mr. Wood was always of the highest importance, and no doubt, every one regretted his absence on that occasion. They were aware that it was proposed to discuss the President's paper, but as he was not present it was obvious they could not go into the subject at this meeting. He, however, begged to inform them that the President intended to furnish some further information to his paper, respecting the cooling power of steam pipes conveying steam to a distance under-ground, and also respecting the expense incurred in conveying coals under-ground. In the meantime he was glad to say there were two papers to be read, viz., one by Mr. Hall, and the other by Mr. Dunn, and as Mr. Hall stood first on the list, his paper would be proceeded with first, if agreeable to the meeting. Before, however, any paper was read, the gentlemen proposed to become members at the last meeting, would be submitted for election.

The following gentlemen were then put to the vote, and declared duly elected:—Mr. Addison Steavenson, Woodifield Colliery, near Darlington; Mr. John Brown, Darlington; Mr. George Robson, Tondu Iron Works, Bridge End, Glamorgan.

The CHAIRMAN next observed, that the President had informed him he had succeeded in obtaining a promise of copies of the Transactions of the Institute of Civil Engineers, in exchange for the Transactions of the Mining Institute. This must be considered very handsome on the part of the Civil Engineers, as they could not perhaps have expected more than copies of their contemporaneous Transactions. The Museum of Practical Geology had promised to send their Transactions; and they also expected a copy of the Geological Survey from the Board of Trade. He begged further to add, that some proceedings had been agreed to by the Council respecting the proposed Mining and Manufacturing College of Practical Science, the particulars of which they would learn by the Secretary reading the Minutes of the Council.

The SECRETARY having read the minutes,

The CHAIRMAN resumed, by observing that, in addressing His Grace the Duke of Northumberland, the Right Hon. the Earl of Durham, and other noblemen and gentlemen, on the subject of the intended College, the Council, judging that these noblemen and gentlemen were only partially acquainted with the proceedings of the Mining Institute of Engineers, consider it desirable to accompany the Prospectus and Circular with copies of the Transactions from the beginning up to the present time. Such a course would be a suitable introduction to the important object they had in view. And this, again, suggested the propriety of keeping the Prospectuses of the College from the public, with a view of first ascertaining the probable amount of subscriptions they would receive at the outset. It would be seen from the Report of the Committee that they do not pledge themselves to any particular line of proceeding until circumstances indicated the course they ought to pursue. If the subscriptions were considerable, that of course would form a point upon which these proceedings would turn: but after all, the Committee must be governed by future events.

The subject here dropped; when

Mr. HALL read a Paper, "On the Coal Measures of Styria, in the Austrian Dominions, including a Report on the Mines of Sann Thall."

The CHAIRMAN, at the termination of the Paper, called the attention of the meeting to the specimens of coal and iron ore accompanying Mr.

Hall's paper, and suggested that a few of the specimens be analyzed.

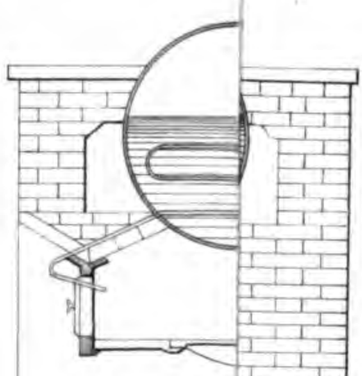
After a brief conversation, in which every one who took part, coincided with the Chairman's views, the following resolution was put and carried:—

"That Dr. Richardson be requested to analyze the specimens, say half a dozen each of the coal and iron ore, presented by Mr. T. Y. Hall, and to lay the result before the Institute, in order that the same may be printed to accompany the Paper."

The next business was the reading of a Paper by Mr Dunn, "On Boiler Explosions."

After which the meeting adjourned.

Enlarged View.



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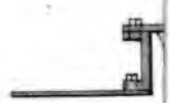
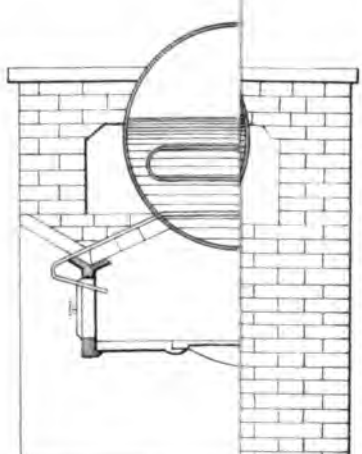
Enlarged View.





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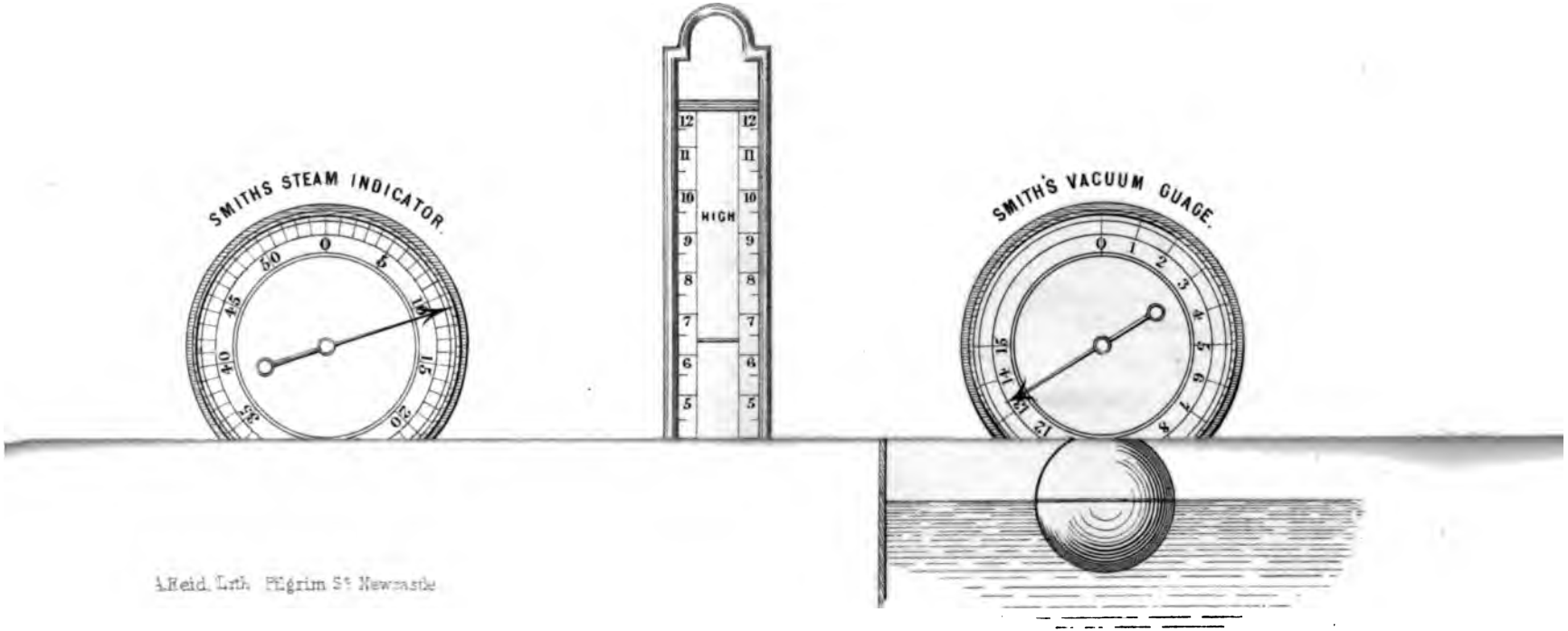

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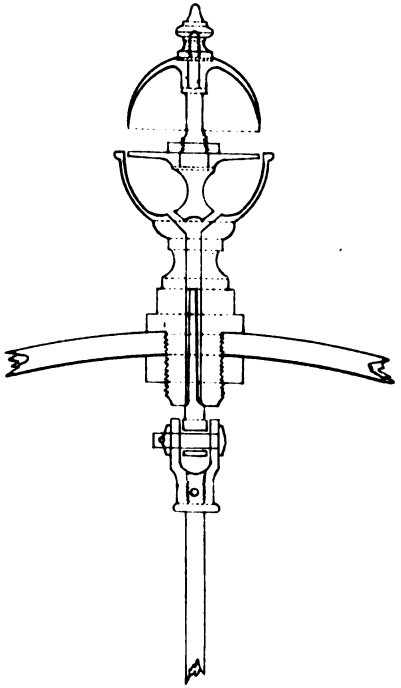

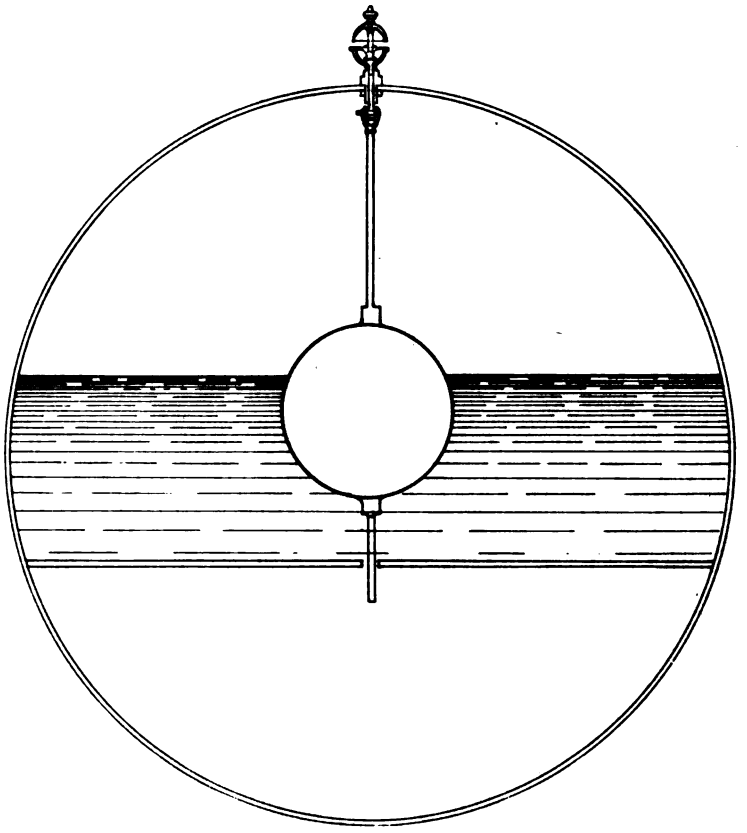

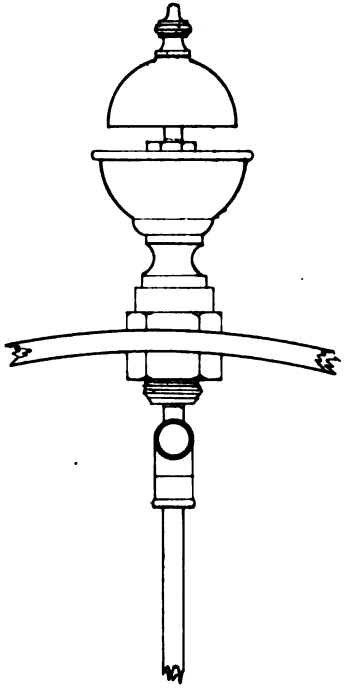

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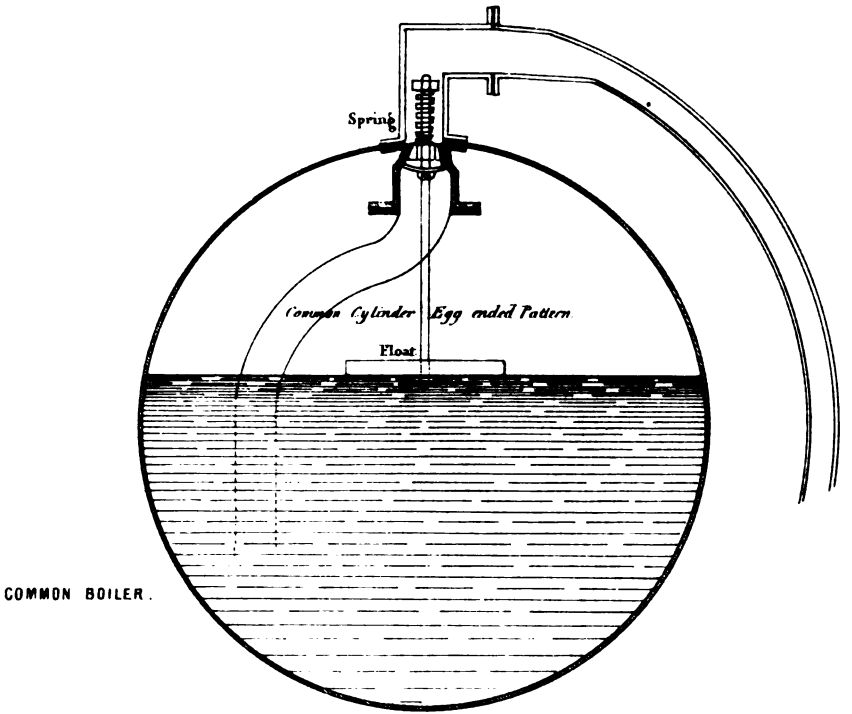

COMMON BOILER.

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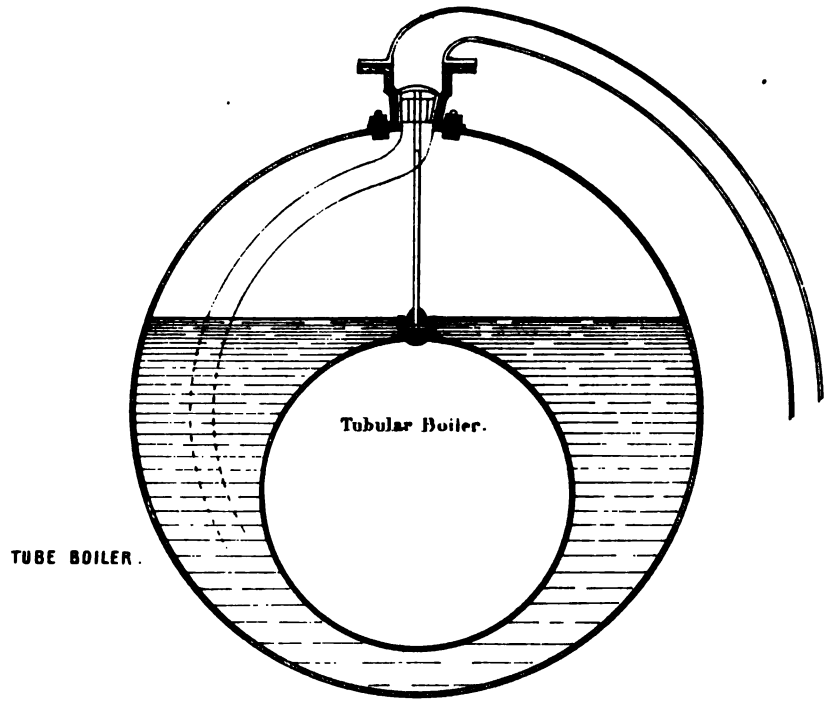

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ON BOILER EXPLOSIONS.

BY MATTHIAS DUNN.

The explosion of boilers has now become as exciting a subject as the explosions of collieries, and in many cases as difficult to account for, but having been engaged in examining witnesses upon the recent cases which have occurred at Kibblesworth and Walker, I have collected together some of the most important parts of the evidence, and have also consulted certain scientific authorities as to the effects of steam and water in connection with hot iron, as well as the ordinary apparatus of boilers in respect to the steam and water communications, &c., with a view of inviting discussion, and of bringing forward the practical talent with which the Northern Institute abounds, to endeavour to devise some means of checking this growing evil.

I have endeavoured to ascertain how far the danger of explosion is increased by the prevailing custom of having four, five, or six boilers all intercommunicated by the same feed and steam pipes, but practical persons seem to think that there is nothing objectionable in this, inasmuch as each boiler has its own branch pipe, with suitable stop valves.

It is understood in practice, that when one boiler is feeding, all the other feed valves should be shut, because, if two valves are open at the same time, the strength of steam in one boiler may force the water out of it into one or other of its neighbours, and so cause the boiler to become suddenly dangerous for want of water.

The quantity of water in high pressure boilers continues to be ascercertained by means of the float or piece of stone suspended or attached to a wire led through the boiler top, and poised by means of a balance-wheel with a weight to denote the rising or falling of the water. This apparatus has been recently improved upon by sundry devices for producing a whistle, or alarum, when the water falls below a certain point.

Amongst the most recent of these applications is Dirck's Patent Anti-explosive Apparatus, Coleman and Co., Proprietors, 32, Moorgate (a drawing of which is annexed).

The Patentee assumes that boiler explosions, for the most part, originate in over-heating, but not necessarily from a deficiency of water, sometimes from the sticking or over weighting of the safety valve, and he has, therefore, invented a means for cooling down the water by the introduction of cold water, to flow through coils of pipes immersed in the water, and discharging by a pipe leading outside.

The introduction of the said cold water to be induced by "*the over-heating of the boiler,*" and its contents acting upon a fusible alloy, which, when melted, opens a valve or water-cock, connected with a cistern above, which allows the water to pass into and through the refrigeratory tubing within the water of the boiler, and discharging within sight of the fireman.

"Combinations of tin, lead, and bismuth, in different proportions, melt at known temperatures, thus in parts of 3, 5, and 8, the alloy melts at 212°, while in parts of 2, 3, and 2, the alloy melts at 270°. Then, as we know the temperatures of given pressures, we can accommodate the alloy to melt at very near the required pressure, which I call the "*danger heat,*" for 15lbs. pressure is 251°, 30lbs. is 270°, and 60lbs. pressure is 309°. It is not meant to substitute the usual guages and safety-valves, but to call attention."

Johnston's Improved Self-Acting Alarm (of which also I append a drawing), is founded upon the assumption that almost all boiler explosions arise from a deficiency of water. He, therefore, proposes to furnish each boiler with the annexed apparatus, so that when the water falls below a certain level, the steam acting upon the instrument produces a whistle. The float, consists of a large "*hollow metal ball,*" made sufficiently heavy that in the falling of the water, it opens the orifice and whistles. This apparatus is now manufacturing by Mr. Watson, High Bridge, the cost being only 40s.

A Third Invention for which the author, Mr. Hall, of London, has taken out a patent, is founded upon the following assumption, viz.:— "That explosions are not occasioned by a constant pressure of steam allowed steadily to increase until its tension is greater than the strength of the boiler, but, by permitting the water to become so low as to expose the plates to a high temperature, they surcharge the steam with caloric far exceeding that due to its pressure, and in injecting an additional supply of water into this heated steam, which acts like a blow. It is also known

that the water level may be raised even by opening the safety valve, which, instead of tending to safety, may thus become the cause of producing the explosion, which opinion is strengthened by the fact that the greater number of accidents occur immediately after starting the engine." He, therefore, proposes a '*water blow off valve*,' to operate when the surface of the water has fallen to a dangerous extent; the said valve might be made self-acting, either by *a float, or what is preferable* a fusible metal cup, enclosing a bolt head to which the valve is attached at the other end, and retaining it in its seat *(see drawing)*. The valve communicating with the water, and kept in position by a rod terminating with a small head, which is held in the cup by soft fusible metal, and the cup riveted to the crown of the tube or boiler. If the tube or furnace be unduly heated, the rod would be released and the valve permitted to open and discharge the water from the boiler, the pipe connected with this apparatus terminating near the bottom of the boiler, the water to be forced up by pressure of steam. The valve being inverted and kept in its place by a small spiral spring, allowing the float to be at liberty until the water falls from it when it opens the valve and releases the water. The cup that is rivetted into the tube is not lead, but another metal, the quickest conductor of heat and most fusible that we can find for the purpose, run into it upon the head of the bolt; it is to do away with the lead plug, for we find that the action of the fire on one side and water on the other, so act upon the lead as to oxidize it, so that it almost becomes tin. We have tried several of the lead plugs which have been in some time, and instead of melting at 415° or 420° they do not melt till nearly 600°, and sometimes as high as 950°, and it is to get over this that we adopt the cup."

"I have had an experiment with the cup standing 2½ inches above the tube, when it melted the fusible metal whilst the water was still on the tube."

His ideas are still further explained in a subsequent letter of 28th November, 1855, viz.:—

These considerations naturally and inevitably lead to the conclusion that safety is alone to be attained by opening a water-blow-off-valve when the surface has fallen to a perilous extent for the purpose of first discharging the water, which is the more dangerous agent, from the boiler, and then the steam operating, in fact, as a safety-valve placed in a more useful and less objectionable position than the present steam-valve, situated on the dome. This valve might be rendered self-acting by a float, or what, perhaps, would be preferable, a fusible metal cup, enclosing a button, by which the valve would be retained in its seat, unless subjected to the temperature at which it was designed to

melt. The accompanying sketch illustrating the principle, represents a valve communicating with the water, and kept in position by a rod which serves for its stem, and terminates with a button cemented with fusible metal into a copper cup riveted to the crown of the boiler. If the furnace should be suddenly heated, the button would be relieved, and the valve permitted to open and discharge the water and steam from the boiler. The boiler might be injured, and, perhaps, the flues destroyed by the fire, but it could not be exploded.

A fourth steam and water gauge, the patent of Mr. Sydney Smith, Hyson Green Works, Nottingham, is highly spoken of and extensively used. *(See drawings).* The following are the remarks by the patentee:—

STEAM INDICATOR.—In construction it is neat, simple, durable, instant in action, and shows every variation of pressure with the most exact and delicate precision, thereby preventing the frequent and disastrous boiler explosions resulting from ignorance as to the actual pressure of steam in the boiler.

For marine boilers the patent steam indicators are well adapted, as they are not affected by the rolling of the vessel or heat of the engine-room, and can be placed in any suitable position, either near the boilers, in the Captain's cabin, or alongside the compass.

MAGNETIC WATER GAUGE.—In consequence of the frequent bursting of the common glass gauge, and the trouble and expense of renewal, a gauge that is not liable to these casualties is much wanted. *The magnetic gauge* is neat in appearance and simple in construction and action, and is not liable to derangement; it is placed on the top of the boiler, near the front; a copper ball float, which rises or falls with the water, is attached to a magnet behind the dial of the gauge, by means of a brass rod, and causes the moveable hand to indicate the height of water with the most exact precision.

CYLINDER WATER GAUGE.—In cases where the upright magnetic water gauge cannot be applied, the *cylinder gauge* is recommended. It is placed in *front* of the boiler, and in principle is similar to the other, except that instead of an upright scale, the magnet attracts a needle round the face of a graduated dial plate, by turning on its axis, worked by a copper ball float. A reference to the sketches will fully explain the working parts.

EXTRACTS FROM CORONERS' INQUESTS AFTER SUNDRY BOILER EXPLOSIONS.

I.—BOILER EXPLOSION AT KIBBLESWORTH COLLIERY, COUNTY OF DURHAM.

An explosion occurred at this colliery on the 19th September, 1855,

by which a poor man was killed, and the circumstances under which it happened seemed to afford a good opportunity of scrutinizing the causes which had preceded this calamity.

The establishment consisted of five cylindrical boilers, each thirty feet by six feet, loaded on the safety-valve, as they expected, at 35lbs. per inch.

The boilers were all intercommon in regard to the steam and feed pipes, having the necessary stop-valves also well fitted up with float apparatus and safety-valves, and managed by steady men. The explosion happened too, at eight o'clock, a.m. The night and day man had changed at six o'clock, and reported that all was in the most satisfactory state at that time. After a long and patient investigation before Mr. Hudson, the Deputy Coroner, a verdict was brought in of accidental death, and in order to put people on their guard against such an oversight as was supposed to have brought about this mishap, I published pretty extensively the following exposition, in order to put persons upon their guard.

TO THE EDITOR OF THE NEWCASTLE JOURNAL.

SIR,—By this explosion an unfortunate young man lost his life, for the boiler was rent into three pieces and driven 150 yards from the place. It very seldom happens that a clear elucidation of the immediate cause of these explosions is arrived at, but in this case it was discovered that *the feed valves belonging to two of the boilers* had been open at the same time, and as proof was given that two hours previous to the explosion all the five boilers were in a perfect working state, no ordinary boiling could have diminished the water to such a dangerous extent. There was, therefore, no room to doubt that, in consequence of the two valves being open, the water in the boiler which exploded had been *primed or driven* into the neighbouring boiler, and in consequence the former had become heated up to redness, whilst it was also obvious that the engineer was at the time in the act of turning on water, which is a very common and natural course to take. I have, therefore, deduced from these examinations some instructions which I will endeavour to make public, as to the course which ought to be taken when a boiler is discovered to be in a dangerous state for want of water:—

1st.—Not to attempt to pull out the fire, because, whilst that is doing, the heat will be more intense, but to set open the fire door, and deaden the fire with green coals, if damp so much the better.

2nd.—To close the pipe communications with the other boiler; but leave the damper open.

3rd.—To set open the discharge steam valves; and not to introduce any water until all is cooled down.

If the proprietors of collieries and manufactories would cause these simple rules to be circulated amongst their operatives, it would tend to warn them what to do in so critical a moment, instead of being left to the natural but dangerous expedient of introducing water.

Since publishing the above remarks, I have reason to believe that the opening of the steam-valve, under such a dangerous state of things, would not be the most prudent course, because the sudden rush of the steam might have a tendency to raise the water of the boiler up against the heated plate, and also to convey to the steam itself (perhaps liquified by extreme heat) so violent a motion, as to produce explosion. I therefore conclude, that beyond insulating the boiler and cooling it down, the less violent change made the better.

II.—WALKER WORKS BOILER EXPLOSION.

Wm. Livingstone's Evidence (Engineer), 1st Day.—This explosion happened on Monday morning, the 8th Oct., whereby one was killed and several others grievously wounded, the boiler was blown into four pieces and carried to a considerable distance from the place. The boiler in question was made of 3-8 inch plate, (one of six all inter-communicated), was twenty-five feet long, six feet eight inches diameter, and loaded with from 35lbs. to 40lbs. per inch. The boiler was pretty old, but had undergone important repairs, so that it was adequately strong for more than the intended pressure. Each boiler had two safety-valves. They had also Smith's indicator attached to the floats to show the quantity of water contained in the boiler. The safety-valves were taken out and examined once a fortnight, and the feed-pipes were fitted with a flap at the bottom, opening upwards to guard against the water being primed up the pipe into the neighbouring boilers. At the time of the explosion the engine had been at work upwards of four hours. The water which fed the boilers was heated, and the boilers were cleaned every fortnight. It was in evidence that half an hour before the explosion the engineman, in answer to a question, said that "*there was rather too much*," and in consequence had shut off the supply to send it to the other boilers, which was corroborated by the fact of the valves being found shut at the time of the explosion. Two of the boilers were closely connected together, and a priming might have taken place, but not likely. He believed there was no want of water at the time. He was at a loss to know why the boiler had been thrown so far from its seat except that there had been a deficiency of water.

Oct. 19th.—The adjourned inquest was resumed, at which I was summoned by the Coroner, S. Reed, to assist in examining evidence and endeavouring to throw some scientific light upon this hitherto mysterious subject.

Wm. Livingstone further examined by M. DUNN.—The safety-valves were found quite free and in good order. One continuous feed-pipe supplied six boilers, each boiler having a branch pipe and valve. If the flaps got out of order the boilers might prime into each other, the flap is placed within four or six inches of the bottom of the boiler. One main steam-pipe supplied all the boilers, each boiler having also a branch pipe and valve. The boilers might prime through the steam-pipes, but he never knew it to be the case. If he found the boiler in a dangerous state he would dampen the fire and draw it, although this, for a time, would increase the intensity of the heat. He would also lift the safety-valve quick as possible, these valves were four inches in diameter, but only three inches in clear space. They had no lead plugs in the boilers; if such had been the case they would have melted out, and have given warning of what was happening. He had seen the lead plug often in locomotive boilers, and thought it might be used in other boilers as well. Had two floats on each boiler. The flap in the boiler feed-pipe was between five and six inches from the bottom, but in some others not more than three or four inches. The flaps were never obstructed in their action by any sediment. It is equally safe to work six boilers together with one pipe as half that number. He had seen lead plugs, but thought the boilers at Walker safe enough without them. He never saw lead plugs used in high-pressure boilers, but had seen them in locomotive engines. The lead plug would melt and extinguish the fire by the rush of water and steam. Yet he could not perceive much advantage in using them.

Wm. Short.—Was boiler smith, and repaired the boilers. About three years ago this boiler underwent a thorough repair; new plates were put on. Was quite capable of bearing a pressure of 50 lbs. per square inch. Thought the boiler could not have exploded if there had been a sufficiency of water in it, even suppose the plates had become heated. After examining the boiler he had come to the conclusion that the boiler had been red hot. The plates had a red appearance, as if over heated by fire. He had seen lead plugs used in cylinder boilers such as this. If a lead plug had been placed near the bottom it would have melted, and have warned the men of danger. He considered it would be better to adopt the lead plugs. It was the bottom that was rent asunder, and both ends were blown out. It was not from the intensity of steam but the want of water.

NOV. 14.—RESUMPTION OF INQUEST.

George Dove, Engineer of the Walker Works.—If the fire of one boiler was kept up while the fire of the other boiler was being withdrawn, it would have the effect of causing the water to flow through the feed pipe into the boiler which had an insufficient supply of water, in case there was no stop valve. The boiler plates would become red hot under a want of water, the steam would then become increased in temperature, and if mixed with water was sure to cause an explosion. He thought no gas was generated in the boiler. When water was admitted into a boiler heated up to 350° or 400° the water would assume a spheroidal shape, would reduce the temperature, and cause an explosion. Had no doubt but that the plates of the boiler had been heated towards red heat, after which, an explosion might occur at any moment. He was of opinion that had been the case with this boiler. There was a steam indicator for the set of boilers, which shewed the pressure. The indicator was Sydney Smith's patent, and was considered a satisfactory check. He thought the boiler had become dangerous from priming, but not by the feed pipe, because of the application of the flap. He thought it had primed through the steam pipe. Independent of the flaps, they have also valves to each boiler to regulate the quantity of water admitted into them. The valves screwed down, and, in case the bottom flap got out of order, the water could be shut off by these valves, and they acted as a check. He would not recommend the *adoption of lead plugs for oblong boilers* without a tube; they might be advantageous for tubular boilers or a boiler with a fire-flue. His reasons were, first, they were out of sight, and secondly, that they would not melt under 594°. There were other metals which might be used with the lead, such as tin and bismuth, which would regulate the melting point to any named degree, but they would not amalgamate and form a plug to be relied upon.

Thomas Bell, one of the Proprietors, was of opinion, that a boiler excessively heated would produce hydrogen gas, provided there was no great pressure of steam in the boiler, because the pressure of steam would split open the boiler before the iron became sufficiently heated to generate the gas. But if there was a low pressure in the boiler, and hydrogen gas did form, it could not explode, owing to the absence of atmospheric air. Water heated into temperature did not produce oxygen and hydrogen gas. If heated, in contact with iron, hydrogen gas alone was generated.

[In illustration of the principle of heat tending to throw water into a

spheroidal shape, an experiment was shown by heating a thin piece of iron *red hot* at the point A,

and B being kept at a lower temperature, when water was put into the cavity A it did not fly away in steam, but danced about in a globe like quicksilver; but upon moving down to the lower temperature of B it immediately exploded into steam. Hence it is inferred that it is not *red heat* which causes the explosion, but some intermediate temperature.]

The CORONER then briefly summed up, and the Jury, after consulting a few minutes, returned a verdict of "Accidental Death."

At the conclusion of the inquest I read the following Paper :—

I have thought proper to lay before the jury assembled at Walker, a few extracts relative to the power of steam, under various circumstances, as bearing upon the enquiry now before the coroner and jury, which may probably serve to lead to the consideration of circumstances by scientific persons; but, after duly considering these and other similar circumstances, I have come to the conclusion that the explosion has originated (from whatever circumstance) in the proper quantity of water in the boiler having been wanting.

Such want of water might take place from neglect of the person in charge, or it might take place from the priming of one boiler into the other, up the steam or feed-pipes, by which means the boilers were intercommunicated. The boilers would appear to have been well guarded against such an incident, each boiler having duplicate safety and feed valves,—the latter being furnished with flaps, within the boiler, for the prevention of the priming. Notwithstanding these precautions the boiler seems to have undergone undue heat; and, although there is no evidence to show that any new feed had been recently admitted, yet I conceive that it is very possible that the agitation of the steam might throw the water within the boiler upon the plates, already so hot as to occasion an instantaneous undue expansion of steam, and so produce the explosion.

I am, therefore, against the opinion that hydrogen gas has occasioned the catastrophe; because it will not explode at an ordinary red heat, and it could not communicate with the boiler fires or with atmospheric air.

With respect to the prevention of such accidents, and under the impression that they almost always originate from want of water (unless the safety-valve either goes wrong or is over-weighted), I am greatly of opinion that the revival of an old practice would be advantageous, viz., to adopt a plug of lead or some alloy which would melt or consume at a temperature between 350 degrees and red heat—as explained by experiment—such plug to be placed in a tube boiler, at the upper part of the tube; and in a common cylindrical boiler half-way between the surface of the water and the boiler bottom. The said plug once consumed, the steam and water would rush out and recall immediate attention to the boiler, which must necessarily then be left to cool down, during which the steam-valves should be gradually opened.

It would be quite proper, whilst the boiler was being cleaned, to punch out the said plug and substitute a new one, to avoid the objection as to oxydation.

The advantage of this over many other devices is its extreme simplicity and freedom from friction or complicity. At any rate, I trust that these remarks will cause investigation and decision amongst practical engineers, so as to diminish these appalling mischiefs.

It is undoubtedly an excellent precaution to adopt a flap, or horse-foot valve, at the foot of the feed pipe, to prevent priming up that pipe.

P.S.—I add to the above report some experiments by Mr. Horsley, engineer, Seghill, made at my request, to show the rate of steam diminution under different circumstances, the boiler being 27½ feet in length, 6 feet in diameter, and the safety-valve having an area of 3 inches.

Steam Indicator 25lbs.	At end of 5 min.	End of 10 min.	End of 15 min.	End of 20 min.
Exp.	lbs.	lbs.	lbs.	lbs.
1 Fire door open	23½	20½	18	16
2 Fire damped	21½	18½	16	14
3 Fire pulled out	22½	19	16	13½

CONSETT BOILER EXPLOSION.

An inquest was held on the 14th November, 1855, from which I give a few extracts from the published evidence, as it seems to lead to a somewhat different conclusion to the two former cases. The boiler was split into two parts, one part flew ninety-one and the other ninety-six yards from the spot.

Thomas Maddison, Brakesman.—There are ten boilers, eight of which are supplied by the same steam-pipe, and the whole ten by the same feed-pipe. They are all fed with cold water.

The CORONER explained that he had consulted the Government as to sending an engineer to examine, but it was not thought necessary.

Mr. Godley, Engineer of the Works.—The water is regulated by one float to each boiler. The person in charge could see the indicator when the water was low. The wire connected with the indicator is oiled every morning, and I never knew it not to act: but if it did stand, the indicator would cease to act. I think there had not been sufficient water in the boiler which exploded. I think that some time before the explosion the boiler had been *sludged*, after which the valve had not been sufficiently closed owing to something having got on the face, and that the water had thus escaped. I examined the feed-valves as well as I could, and found that the valve belonging to that boiler was open about a quarter of an inch. From the way we feed our boilers they cannot prime over. I

found that immediately above the fire-bridge the plates had the *appearance of having been red hot, and that the plate was torn away.* Thickness of plate, three-eighths of an inch. Boiler was perfectly sound, and the water is kept about a foot above the flue, which leaves a space of 2 feet to 2 feet 2 inches for the generation of steam. *I conclude that at the time of the explosion the deceased had found the boiler was short of water, and was turning the feed-pipe. The boilers are supplied with hot water. If I saw a boiler ready to explode in consequence of a want of water, I would dampen the fire, open the fire-doors, and by no means draw out the fire. I would also put the damper down. Drawing out the fire would increase the heat. I would not put the feed on.*

Samuel Elliott.—I think that between the time when I examined the boiler to the time of the explosion, the water could not have sufficiently diminished by heating to cause the explosion.

Matthew Gardner, Boiler Inspector.—I had examined the boiler which exploded a week before the explosion, and concluded it was a safe boiler. I think the boiler exploded from a want of water; because it would not burst at the low pressure of 31 lbs. per inch, which is the pressure at which we work them. We never worked any of our boilers at a greater pressure than 40lbs. I examined the boiler after the explosion and found no flaw or thin place, or any appearance of the plates having given way. *The side plates had the appearance of having been hot—the plates had a blue colour.*

Verdict, "Accidental Death."

I will now submit a few extracts, from various authorities, touching the nature of steam, air, and metals, which are more or less involved in the question of the explosion of boilers, viz:—

The expansion of steam at 212° in comparison with water, is stated at 1800 to 1.

The density of water in proportion to air 832 to 1, and 212° is the boiling point of water.

If common steam be enclosed in a vessel and exposed to a pressure greater than two atmospheres, it will be wholly condensed into water, provided no elevation of the temperature be allowed ("Young's Philosophy"), being the force of cohesion by means of pressure. And air compressed to

half its dimensions has its temperature raised about 50° of F., $\frac{1}{180}$th part compressed will raise it a degree.

The elasticity of aeriform fluids is increased about $\frac{1}{300}$th part for every degree of heat, therefore, if the heat be raised to more than 5000° the force of each grain of water converted into steam will only be increased *tenfold.*

When water is heated up to 212°, the vapour from it resists compression and makes an effort to expand with a force exceeding that of gunpowder, and this effect is continued with *diminished intensity* as the bulk of the steam increases, till it has arrived at 1800 times the bulk of the water that produced it, when it becomes entirely inert, and has no more tendency to burst a vessel than if it were filled with common air; the pressure of the air and the tendency of the steam to further expansion being an exact balance to each other.

Steam at 212° is just equal to the pressure of the atmosphere, but by increasing the degrees of heat the following results occur:—

	lbs. per Square Inch.	Temperature Fahrenheit.	Equal Inches of Mercury.
Pressure predominating over the atmosphere acting on the safety-valve.	2½	220	——
	10	241	20·6
	15	252	30·9
	20	261	41·2
	30	276	61·8
	35	283	——
	40	289	82·4
	50	300	——

So that by a small addition of temperature an expansive power may be given to from 40 to 400 times and upwards its bulk or any other proportion.

A cubic inch of water will produce a cubic foot (1728 inches) of steam.

Latent heat of steam at the common pressure of the atmosphere is found to be 1000°, the sensible or thermometric heat being 212° less 32° (freezing point) = 180°, or 1000° added to 180° = 1180°.

Quantity of caloric which heats water 1°, heats mercury 3·16, specific caloric of water 1°, mercury 0·31.

Water is 914 times as heavy as air at the surface of the earth. Its greatest density is 42·5, and if heated above or below that point it undergoes expansion in both cases. Thus at 32° and 53° are the same expansion, same at 80° as at 5°.—(Dalton).

EXPANSION OF WATER BY HEAT AT

42·5			Greatest Density			1·
102	....	....	....	....	....	1·00672
122	....	....	....	....	....	1·01116
162	....	....	....	....	....	1·02245
202	....	....	....	....	....	1·03634
212	....		Boiling Point.		....	1·04012

The expansion of air is eight times greater than water, and water forty-five times greater than iron, the temperatures of each substance being supposed raised from 32° to 212°. The more bodies are heated the less they weigh.

Hydrogen gas is produced by water in contact with iron heated to ignition, but will not explode at red heat in itself. It is not explosive without a large proportion of oxygen, the most explosive mixture being 2 of hydrogen and 1 of oxygen.

Hydrogen is the lightest of all substances except light and caloric, and when pure it is nearly thirteen times lighter than common air. Under heat the oxygen is absorbed by the iron, leaving the hydrogen inexplosive, *which seems to set at rest a common opinion that explosions sometimes take place from the gas which is formed within the boiler.* Heat is capable of producing a galvanic current, the intensity of which is proportional to that of the producing agent—(Young).

One hundred inches of hydrogen do not weigh three grains, air thirty-one grains. Hydrogen gas is separated by passing steam through a red-hot iron tube.

Hydrogen generally contains half its weight of water.

Iron contains a capacity of $\frac{1}{8}$th that of water, for heat;—lead, $\frac{1}{24}$th; silver, $\frac{1}{12}$th; mercury, $\frac{1}{30}$th. Copper contains nearly the same quantity of heat in a given bulk as water, but lead and glass about one-half only.

Cohesive strength of iron at different temperatures :—

32° to 80°	56·00	This Table exhibits a singular decrepancy in the increasing and diminishing ratio which is not accounted for.
570°	66·50	
720°	55·00	
1,050°	32·00	
3,000° fluid query.		

Boiler plate is found to increase in tenacity till it reaches 550, after which it diminishes.

The lowest temperature which gives discolouration to iron (a straw

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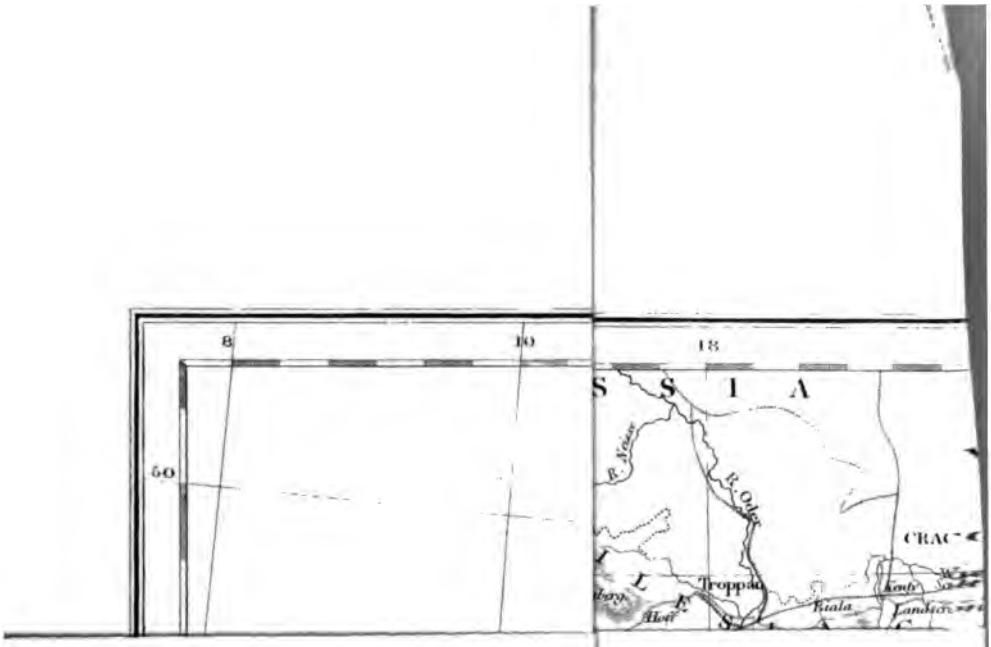
8
10
18
S S I A
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R. Neisse
R. Oder
CRAC
Troppau
Biala
Kenty
Landsch

ON THE

COAL MEASURES OF STYRIA,

IN THE

AUSTRIAN DOMINIONS:

COMPARING THE SAME WITH THE COUNTIES OF DURHAM AND NORTHUMBERLAND, AND THE UNITED KINGDOM, INCLUDING A REPORT ON THE MINES OF THE SANN THAL.

By THOS. Y. HALL,

NEWCASTLE-ON-TYNE, DECEMBER, 6, 1855.

INTRODUCTION.

In fulfilment of a promise made to the President of the Institution, I have now the pleasure to furnish some detailed information relating to coal fields in Austria, which I visited last year, and of which I have prepared some views, maps, and sections, together with a few specimens, and shall be most happy to present them to the Museum of this Society, with sections showing all the coal seams of our northern coal field districts (30-in. in depth), and specimens of same from each, with iron ores.

My object in making this communication, is to lay before the members such plain matters of fact as came under my observation, and which form the materials of a Report now in progress. I have considered that such information as I have collected, ought in the first instance, to be laid before this Society, founded as it is in the metropolis of the most important coal fields in Great Britain. We find Newcastle-upon-Tyne coal districts, not only in ancient days, but at the present time, celebrated for their mineral treasures, also the birth-place of railways, locomotive machinery, our Stephensons and Hawthorns, and by its commercial

enterprise, industry, and wealth, in other manufactories, is one of the most flourishing ports in the kingdom. It is also of importance that data relating to other mining districts should be collected and preserved, —more especially as regards the carboniferous formation.

The amount of capital invested in collieries in Durham and Northumberland is known to exceed twenty millions, exclusive of the large capital employed in shipping (say ten millions sterling), for eight or nine million tons of coal yearly.* These counties produce more than fifteen million of tons of coal per annum, a quantity which may be considered about one-fourth of the total quantity of coal raised in the British Isles; the investment of capital being, equal to one-fourth of that embarked in all the mining operations of the kingdom. It may be added, that the capital employed in these two counties, and the annual produce raised, are nearly equal to those of the coal mines of America, France, Belgium, Prussia, and Austria united.†

AUSTRIA SUPPLIED WITH ENGLISH COAL.

Austria is supplied with coal and coke from the great coal fields of which Newcastle-upon-Tyne is the outport. Vessels are seen discharging their freights of Durham and Northumberland coal at the quays of Trieste and Venice, when at the same time Austria possesses coal fields of her own. The carboniferous formation is to be found at no great distance from the first named seaport. I visited those Austrian coal districts in the Summer of 1854, for the purpose of investigating the mineral capabilities of the same. At that time the freight of ships from England was high, and the price of coal was also high,—the former being nearly double, and the latter twenty-five per cent. more than during many previous years; the details relating to which will appear in the sequel.

LIMITED SUPPLY OF COAL IN AUSTRIA.

In comparing the coal fields of Austria with those of the coal-bearing counties in England, viz.:—Durham, Northumberland, Cumberland,

* This large quantity of coals yearly, cannot be put down at much less than 3½ millions sterling yearly, and the value of the shipping required to carry away the same from the different shipping places will amount to ten millions sterling.—The large quantities of coal and coke now sent from the Durham coalfield, from the Wear and Tees Wallsend districts South, and to London by public railways, necessarily reduce the quantities that would be sent by shipping from the east coast by German ocean.

† My detail of the mineral produce of these Counties, as well as the probable duration of our coal field, will be found in the concluding chapter, page 257, Vol. 2, 1853-4, of the "Transactions of the North of England Institute of Mining Engineers."

Lancashire, Yorkshire, Derbyshire, Leicestershire, Staffordshire, Scotland, Wales, and others, *(see tabular pages)*, they appear, as far as regards their working and the amount of trade resulting therefrom, very insignificant, especially when we know the area of that empire to be more than one-third greater than that of the British Isles. While the United Kingdom, irrespective of Ireland, produces annually upwards of 64½ million tons of coal, Durham and Northumberland alone contributing, inclusive of home consumption, 15½ millions from eighty colleries, with 190 coal pits working coals for sea sale (these occupy nearly the whole of the coal field area, consisting of 750 square miles, equivalent to 480,000 acres*), the Austrian dominions scarcely yield one million of tons, and, consequently, are obliged to import coal from England, Belgium, and Prussia, for the use of her manufactures and general requirements. The fuel used for household, as well as other purposes, is, excepting a limited supply of lignite or wood-coal in Styria, more than nine-tenths wood and charcoal. So difficult are the means of transit from any of the workable coal mines in Austria to the seaports on the Adriatic, that the expense of conveying it thither increases the cost to as much as it can be procured for from Newcastle-upon-Tyne and adjacent ports on the eastern coast, or from other shipping ports like Liverpool or Birkenhead and those of Scotland and Wales.

PIG IRON.

Comparative Statement of Iron produced in Austria and other countries with Durham and Northumberland, Staffordshire, Scotland, South Wales, and the British Isles.

In the production of iron alone, the district of Durham and Northumberland has increased, up to the present time, very rapidly, especially since the account was furnished in 1854, by Robert Hunt, Esq., of the total quantity obtained from fifty-two furnaces, 275,000 tons, and from the whole British Isles 3,069,838 tons. The additional number of superior furnaces (making not less than 80), in the Durham and Northumberland iron district, which are, or shortly will be, in active operation, has brought about this important result, and has, or may next year, increase the quantity working to 130 tons each furnace weekly, making this district alone 500,000 tons annually. This makes the annual production for the British Isles, without calculating the improvements and increase of producing means in any of the other principal iron districts, 3,250,000 tons. In dividing these Islands into four districts, naming as a fifth the minor

* See shaded part of Plate 9.

places where this ore is manufactured into pig metal, it is remarkable that four of them, Scotland, Staffordshire, South Wales, with Durham and Northumberland, actually supply more than two and three quarter million of tons out of the three and a quarter million tons produced yearly. The quantities are—

		TONS.	
No. 1.	Scotland	807,600	
„ 2.	Staffordshire	796,604	
„ 3.	South Wales	750,000	
„ 4.	Durham and Northumberland district	500,000	2,854,204

From the above facts it will be seen that the last places named, Durham and Northumberland, even the smallest at present, can supply iron in much greater quantity than, nay more than double, and the other three still more, nay treble, the whole of that produced from the whole Austrian Empire yearly. The minor places in England and Wales referred to, are Derbyshire, Shropshire, Yorkshire, Flintshire, Gloucestershire, Cumberland and Lancashire. They severally contribute, as under, to the total:—

		TONS	
5	Derbyshire	127,500	
	Yorkshire	73,444	
	Gloucestershire	21,000	
	Shropshire	124,800	
	Flintshire	32,000	
	Cumberland and Lancashire, only	20,000	398,744

From these statistics we obtain the grand totals of 3¼ million tons.

The quantity for Durham and Northumberland, although gratifyingly large, will shortly, from the suitable coal and limestone at hand, and the increase in railways public and private, far exceed, I have no doubt, the most sanguine of our expectations. The opening out of the extensive clay and magnetic (Rosedale) iron ore districts of Cleveland, and two maiden districts such as Redesdale and Hareshaw mines, with eight furnaces already erected on the North Tyne, Northumberland, in the immediate vicinity of those still richer beds of clay iron ore, with suitable coal found at Plashets, near the same ores, also by the construction of the Border Counties Railway from near Hexham, off the Newcastle and Carlisle line, confirm these expecations. Similar advantages will in like manner be derived by the Marley Hill Coal Company having their private railway lines extended to Conside iron works, also the proposed Union railway from the Newcastle and Carlisle, at Stocksfield station, connecting the Tyne districts where the best coal abounds with the (except in coal), metallic fertility of the Clevelan Hills. The Towlaw (Weardale,) and Conside and other extensive ir orks will, by this and other lines,

besides the Tyne having sea-craft and tidal water to Blaydon and Stella, also railways connecting the ores with the Tyne, and suitable coal and limestone in Durham, which can be brought cheap at short distances to each other, be to the mutual benefit and pecuniary advantage of all the parties concerned.

The necessity for these extra railways will, as regards Cumberland, be at once apparent from the well-known fact, that the Cumberland ores, which are of the hematite best quality, are sent from the neighbourhood of Egremont to the furnaces of Durham and Northumberland by railway, besides Scotland, and even shipped to other places to smelt. Cleveland ores are of qualities differing from the other district ores, and when made into pig metal are termed cold and hot short iron. *(See Appendix).* The actual quantity of pig iron produced in Cumberland bears so small a proportion to the raw material they obtain and sell, that on no other ground than the absence of good coal for smelting and forging purposes can these circumstances be explained, it being hematite ore, which is rich and *expensive,* and (to make it sell cheaper) generally requires mixing (as it does not smelt well alone) with the clay iron ores found at Cleveland and elsewhere. The clay ores at Rothbury, and the North Tyne in Northumberland, are found in the mountain limestone with thin seams of coal near the same, and each of which (like Weardale,) differ as regards the clay that they contain, which it is very important to know.

PIG METAL PRODUCED IN ENGLAND AND OTHER FOREIGN COUNTRIES.

Mr. J. Kenyon Blackwell, F.G.S., the eminent authority on iron, its manufacture, and trade, in a Paper read before the Society of Arts, states that the total amount of the annual production of pig iron, from a careful comparison of various authorities, appears to be at present nearly 6,000,000 tons, divided as follows, amongst the principal producing countries.

	Tons Coal.*	Tons Pig Metal.		Tons Coal.*	Tons Pig Metal.
Great Britain	64,500,000	3,000,000	Belgium	5,000.000	200,000
France	4,200,000	750,000	Russia	Not known	200,000
U. S. of America	6,000,000	750,000	Sweden	Do.	150,000
Prussia	3,500,000	300,000	Various German States	Do.	100,000
Austria	1,000,000	250,000	Other Countries	Do.	300,000

* The quantities of Coal are added by the Writer of this Paper.

The immense production of iron in Great Britain, amounting, as will be seen from these statistics, to one-half of the whole, rests on the almost inexhaustible supply of mineral fuel, and on the abundance of ores of the earthy or black carbonates in most of the coal-fields. About four-fifths of the iron produce in this country is made in nearly equal proportions in the three great districts of South Wales, South Staffordshire and Scotland; Durham and Northumberland follow next. In France, the ores of iron are distributed over so extensive an area, that they are worked in nearly sixty departments. Prussia stands next to France, and is rapidly increasing, its resources in ore and mineral fuel being large. In Austria, the iron industry is extended over nearly all the provinces of the Empire. The iron industry of the United States is already highly important, and

capable of great extension, which must, in a great degree, be guided by the price at which England can afford to supply it at as compared with the cost of production in America, or any other foreign country, by the available means of transport, and the facility with which the ore can be brought into proximity with the fuel, (and hence to markets, often all at great distances). But the carboniferous regions of America have hitherto been so imperfectly explored that it cannot he determined with certainty to what extent ores may hereafter be found in them. Mr. Blackwell proposes, in his next Papers, to examine the nature of the various processes followed in the manufacture of iron, to give some account of the evidences of progress of this industry at home and abroad, derived from specimens shewn at the Paris Exhibition. Where it was remarked, Great Britain, to judge by ore specimens displayed, appeared the poorest instead of the richest iron producing country in the world. The object of the Papers is to determine by what means Great Britain may preserve her present prominent position, and compete with the numerous rivals whom the extension of commerce and civilization is bringing forward.

WANT OF ROADS AND CAPITAL GREAT DRAWBACKS TO MINING ENTERPRISE IN AUSTRIA.

The great drawback, to the profitable working of the coal mines of Austria, is the want of cheap and rapid conveyance from their adit levels or pits to the markets. This difficulty, however, is now being overcome by the construction of railways throughout the empire, and, as I shall show to the present meeting, the mineral resources of the southern provinces are likely in this way soon to be developed. Besides this hitherto great obstacle to mining enterprise to be contended with in Austria, another one has been the want of capital necessary to erect proper machinery, and employ skilled labour to work in the modes we have adopted in our own mines. I find different foreign districts require different modes and motive powers.

COLLIERIES, PUBLIC RAILROADS, DOCKS, CANALS AND SHIPPING IN ENGLAND.

When we look at the immense capital invested even in our Durham and Northumberland collieries and works connected with them, not overrated at 29 millions sterling with offshoots near and at a distance, and the ships engaged in the carrying department, and by taking only a very small portion for the three other coal districts named from the immense capitals employed in the public railways, shipping, with canals, ports, harbours, and docks, which will increase the colliery capital, when England Wales and Scotland are included, to 132 millions sterling, we cannot but admit the vast superiority of our position. When we consider, too, the impetus given to mining enterprise in England, by the above expenditure for collieries, and of 286 millions sterling on the

large number of public railways,* (many not yet finished,) and on public docks other large sums have been expended, to say nothing at present about the further large amount expended on canals in the southern counties, where at this time they are trying an improved mode of leading, instead of horse-haulage, and an improved system of steam power, applied with single paddle or screw propeller, in small boats prepared for the purpose, which has recently been found, at the canal connected with the Earl of Balcarras and Crawford's collieries, near Wigan, to be a most excellent and much more economical system than any in previous operation, effecting a great saving even on the charges for coal conveyed on public railways,† we are the more disposed to admit, and we cannot but marvel at our vast resources as compared with those of Austria. In undertakings like those just named, Austria has not, as will be shown by and by, as yet expended a hundredth part of the amount of capital that there has been disbursed in the British Isles, either for railroads, canals, shipping, or for the use of mineral production; neither does Austria produce one-hundredth part of the annual value of mineral production which is done in the British Isles. A more detailed account of capital and quantities will be shown in a tabular statement. *(See Pages* 68, 69, 70.*)*

ACTUAL QUANTITY OF COAL PRODUCED IN AUSTRIA.

I may here mention that the quantity of coal produced last year did not exceed 900,000 tons, a quantity easily worked by several large coal proprietors in Durham, viz.:—The Most Honourable Frances Ann Marchioness of Londonderry, the Earl of Durham, Nicholas Wood, Esq., Tees Wallsend, Edward Richardson, Esq.; and other large companies such as Hetton, Haswell, Thornley, South Hetton, Robson and Jackson's pits (Hartlepool West Dock), &c.; and further to to illustrate the subject, I may state that five coal pits in Durham or

* Viz.:—175 public railways in England, 37 in Scotland, and 45 in Ireland; independent of the above large expenditure, there is still a large amount of outlay going on daily by those public companies, who have got Acts of Parliament, which enables them to borrow a sum of sixty millions sterling. See appended particulars.

† Therefore, if by applying a mere change in the construction of the paddle or screw for canal steamboats gives so much less wave or friction, may not the like be applied to ocean steamers.—All the canals in the United Kingdom, exclusive of those under five miles long, amount to 80 corporations, with a revenue of £800,000 sterling after deducting expences, which amount to £80 per mile. The above 800,000 would pay 6 per cent. per annum on 15 millions capital.

Northumberland, varying in depth from 1,000 to 1,500, or even 1,800 feet, when working with steam engines from 60* to 80-horse power, the seams of coal lying under the deepest Hutton seam could annually produce, either in the best or steam coal, on the east sea coast where the pits are deepest, or even more in the western coal district for our best coking coal where the coal seams are at much less depth, more than is produced over the whole Austrian empire.

WANT OF TIDAL RIVERS AND HARBOURS IN AUSTRIA.

The want of tidal harbours in the proximity of the Austrian coal fields is also a drawback to their development. In our own tidal seaports a large export trade necessarily gives an impetus to trading in coal. In this respect, it may be said, that Austria is naturally deficient. Austria having no tidal rivers, the tides at the seaports in the Adriatic have scarcely any perceptible rise and fall, that at Trieste being not more than one foot at the highest, and at Venice about a foot and a half. It is to be remarked, that it is this property possessed by our rivers and harbours (and few more remarkable in this respect than the Tyne and Wear), that has been of such great benefit to the export of our coal. In a river of ordinary magnitude, with a tidal rise of from 10 to 14 feet, a merchant ship of the best class is able to ascend at high tide in 22 to 24 feet of water, and in capacious basins like the South and North Docks at Sunderland, or those made and in progress at Hay-hole and Jarrow on the Tyne, vessels take in cargoes of eight hundred tons of coal or other merchandise, without grounding or having their sides or timbers in any way injured; and it must be borne in mind that at this period, independent of the magnificent screw steamers which are now, and will be much more used, in consequence of their great regularity and facility of despatch at each port, the class of ships built are very much superior to those of former times. Owners and captains invariably seek to obtain floating accommodation for their vessels, which now can be had in upwards of 24 feet in the Tyne and Wear rivers and docks, and

* As a proof, the writer of this Paper has, for months produced at a greater rate, by one 60-horse steam engine, from one pit at 1100 feet, at South Hetton, in 1834, and at the present date (1856) it has not been exceeded, even at that depth, since the writer introduced guides and cages in the pit shafts in this neighbourhood, (which work at much greater speed so regularly), and with his further introduction of tub carriages with boggy wheels and edge rails into the pit workings underground, effecting such changes as has caused a saving in the working of coal generally throughout the coal trade of about 1s. 6d. per ton on all coals sold.

Hartlepool east and west docks. The want of sufficient tidal rise in the rivers in the Adriatic seacoast must permanently prevent any great river traffic in the article of coals; the Mediterranean sea now becoming more like an extensive harbour.

ASCERTAINED STATE OF THE AUSTRIAN COAL MINES.

The present condition, therefore, of the Austrian coal fields and the trade itself, so far as developed, may not inaptly be compared to the condition history informs us of the Durham and Northumberland coal mines in the days of the *Romans*, or even so late as in the fourteenth and fifteenth centuries. That coal fields, and other minerals exist to a great extent in the southern provinces I am confident, and my opinion and observations on both points have been fully corroborated by those of Mr. S. Mossman, a practical geologist, who accompanied me in my tour of inspection.

EXTENT OF THE MINES IN STYRIA.

This brings me to the object of my journey, viz.:—Some account of the Coal Fields in the Valley of the Sann, in the duchy of Styria. This district has been famous throughout all time for its mines, and especially for the abundance and superior quality of its iron ores. At the present day it stands in relation to Austria what Cornwall is to England. In its mountain ranges are to be found deposits of every known metalliferous substance useful to man, with the advantage of very extensive forests, and an unknown extent of coal available on the spot to render these ores of great commercial importance. If we turn to the history of Styria, we find that the mineral resources of the country were known to the Romans, who worked some shallow mines in Lower Styria, at that period called Pannonia. It was not, however, until the Germans penetrated to the south that the vast extent of its mineral treasures was known. The practical miners from Saxony and the north of Europe, who emigrated there from time to time, were not long in discovering its extensive mines of iron and lead. Of the former, some idea may be formed from the ascertained extent of the Erzberg mine near Burck, which consists of a mountain measuring 2840 feet in height, and having a circumference at its base of nearly 5 miles, producing vast quantities of iron ore, yielding a large per centage of pure metal. This ore has been worked for many centuries, and is so uniform that it is quarried from the surface, and the iron produced has been highly prized, not only in Europe, but in America

for its richness. At the present time there are upwards of 5000 men employed in Styria. At all their iron mines and furnaces the quantity annually produced barely exceeds 220,000 tons of iron. Of lead mines, those of Blerberg, near Villach, are the most extensive, yet they only yield annually about 1800 tons of metal (less than one-fifth of the produce of the W. B. mines, at Allenheads, in Northumberland). Altogether there are 300 government and private mines and smelting works in Styria, including the coal mines at Buchberg, Petschounig, and Riffingost, which I inspected in the circle of Cilli.

ON THE MINING POPULATION OF STYRIA.

While the iron and lead mines have been thus brought into operation by the enterprise of the German population, scarcely anything has been done to work the deposits of coal, which, in a hundred localities, are seen cropping out on the mountains. Two causes have apparently prevented this, viz.:—the abundance of wood fuel to be had in the interminable forests of Styria, and the disinclination of the Sclavonic population (who form the peasantry) to all underground labour; which labour, from the great distance of their local habitations from the mines, is rendered almost nugatory. When a light railway is laid from Cilli to the mines the change of motive power might obviate this; hence the great importance of more capital, which will, in my opinion, be employed ere long. Everywhere throughout this region the inhabitants burn pine wood, and, excepting in a few cotton factories, the manufacturers do the same. The locomotives (some of which were got from America) burn *wood;* but the engines most in use have an extra number of wheels and the *long boiler,* the invention of our own Stephenson (the engines being confined to certain light loads). In Austria, like America, many of the coal seams *crop* out in the mountain sides, yet each country is largely supplied with coal, metal, and iron from England, although both these countries have railroads laid, and engines running *over* the very seams of coal and ores now being worked, and others about to be placed in working conditions.

This want of energy and means on the part of the Styrian people to carry out coal mining operations, shows the necessity for employing English or other foreign capital and experience to bring out the national resources, for, though the Styrians are slow in commercial matters, they are able and willing labourers; all credit be given to them for peaceful and industrious habits, which they possess in an eminent

degree. They, however, are not as yet a people fit to produce or expand the mineral wealth of the country they inhabit, while their Austrian masters are too poor to invest sufficient capital; nay, even the mines belonging to Government are much neglected, or why use wood for locomotive power, or in mining operations on a great scale? They are a people content with a subsistence from their labours on the surface of the ground, and have not sought for wealth in the bowels of the earth, consequently, they have for centuries trod above the dormant minerals and coal fields, without, so far as I could judge, the desire of turning them to marketable account.

SUMMARY DESCRIPTION OF THE PROPERTIES INSPECTED.

Of these coal fields, the one which forms the subject of this Paper was brought under my notice as forming a valuable investment for English capital, and the application of new and improved appliances in coal mining similar to those used in this country. The particulars of the estate, which contains these mines, as laid before me, were of the most favourable character, and were the means of inducing me to undertake a pleasant though expensive journey for the purpose of ascertaining the facts of the case. A personal inspection (aided by a practical geologist and two interpreters) was absolutely necessary, having friends who had offered to purchase the mines, if my report should be favourable. I have not as yet rendered such report, or recommended the purchase of such properties. Nevertheless, the opportunity enabled me to add greatly to my knowledge of foreign coal mines, and I entertain an opinion that this communication may be of value to others. Without entering into the details of the estate offered for sale, suffice it to say that it was valued at 1,000,000 Austrian florins, or about £75,000 sterling, and consisted of a grand palatial mansion or *schloss*, with garden and domain; a farm of considerable size, with a water-driven flour mill, and three smaller farms; a silk producing establishment, with extensive mulberry plantations containing 300,000 trees, with vast numbers of silk worms, and extensive works for rearing the insects; a vineyard; a brick manufactory; a fishing establishment on the river Sann; an extensive pine forest, and two of smaller dimensions (it may be necessary for me here to remark that the minerals can be obtained without any of this surface property, which I consider is over-estimated); twelve coal mines opened and at work; and the same number of grants from the Government to work the coal.

GENERAL CHARACTER OF PART OF THE NEW CILLI ESTATE.

The whole of the property called the New Cilli Estate is situated in the Sann Thal or valley of the Sann River, a tributary of the Danube, near the town of Cilli in the circle of that name, in the Duchy of Styria, in Southern Austria, and was announced as the property of Herr Von Hausmann, an Austrian gentleman, who was impoverished, not only by the Revolution of 1848, but who had expended unprofitably, both time and means in attempting to open out the mineral resources of the district, previous to my visit. Not to trespass more upon your time than is really necessary with such matters, many of which might be added if I did not consider them irrelevant to the subject, I shall proceed to lay before you the particulars of this coal field, and the mines in operation, with the mode of working them, their general character and formation, the quantity they are estimated to produce, which I have put down at a *very insignificant amount for commencement*, and their probable duration (the cost of plant for the commencement must be considered ample for the small production); the selling price and rates charged for railway carriage to the markets; together with some general remarks, illustrated by maps and sections, and a few specimens of the coal and ores collected during my tour of inspection. The names of the coal and other minerals, with analysis of the same, (to compare with our own different coal and ores) by Dr. Richardson and Mr. Browell, of Newcastle, will be found in the Appendix.

INTRODUCTION TO TABULAR ACCOUNT OF CAPITAL FOR MINERAL PRODUCTIONS IN DIFFERENT DISTRICTS AND THROUGHOUT THE UNITED KINGDOM—ALSO, QUANTITIES, NUMBER OF WORK PEOPLE, AND DIFFERENT CHARGES ON YEARLY PRODUCTION.

It is obvious that in endeavouring to present any general view of the importance of the mineral productions of Great Britain, and of the enormous wealth which, in the form of capital, is either directly or indirectly employed in raising and conveying minerals, an approximation, as regards capital, is all that can be arrived at. The quantities and value of production can be easily ascertained. In order, however, to present as clear a view of the subject as the case will admit, I take the different districts of Great Britain; I then take Durham and Northumberland as my guide for forming other statements, and then view these first separately, viz.,

one for our Great Northern coal, ore, and iron districts (A 1, or No. 1 A), and afterwards several other countries collectively, (No. 2 B, 3 C, and 4 D), on such authenticated data for quantities as has now been obtained, or for direct capital; also No. 5 E abstract, showing extension of capital on such reasonable estimates as can be formed. The materials for such calculations have, indeed, hitherto been few and difficult to procure, but the very useful productions of Robert Hunt, Esq., of the Government Office of Mining Records, are doing much to afford numerous and important details, some of which I have found of the greatest use in obtaining the quantities shown in the statements now under consideration.

The following are the districts which, in the statements hereafter, are respectively headed for "Coal and Coke," and numbered from one to four for coal alone. Value at the pit's mouth is afterwards shown in tabular form E with more indirect extra capital and also extra expense. No. 6 F, shows the other minerals, principally iron in pig, tin and lead, (white lead,) zinc, alkali, cement, and clays. The latter is worked extensively, and now forms a very important item, the sale of which amounts to a large sum yearly, both in its raw state and when manufactured into firebrick and other useful articles. No. 7 G, takes in the *malleable* iron in bar, sheet, and steel, made from out of two-thirds of the whole amount of pig metal produced. Such is the advance price obtained on the sale by extra labour, all done mostly upon or near the same plant where the pig metal is made, and this at £6 12s. 6d. per ton extra at the present time, amounts to £9,003,500 extra to the above; then £1,000,000 for clays, added to Mr. Hunt's statement, makes it amount to £14,600,922, besides the £9,003,500 for malleable iron and steel. This large amount is exclusive of coal and coke, which will appear in tabular form, showing capital, yearly quantities, number of workpeople, with the total amount of produce divided under six different heads. In tabular form H, will be shown the cost of workpeople (1), materials and agency (2), rents (3), interest (4), leading (5), and shipping (6), to make up the total expenditure for yearly production of coal, coke clay, ores, and iron, which sales amount to £53,000,000 sterling yearly.

TABLES, No. 1, 2, 3, and 4, statement of Direct Capitals employed in Collieries by Coal Owners, and Yearly Production of each District.

	Names of Districts and Capital.	Workpeople employed in each district.	Yearly production of each district at mines	Total production of each district in tons		Total value at the pits.
No. 1.	Durham and Northumberland - - - -		Tons. 15,500,000	Tons. 15,500,000	Per ton at 6s6d	£ 5,037,500
	Aboveground at pits & offshoots, say - -	Way-leave rents per ton, say 2d. For average leading charges, on private railway 1s. 0d.				903,166
	15,500, or 3-5ths hewers in pits underground.					
	3,200 | 1,400 | 1,200 | 7,800 | or 1-6th safety staffmen boys belongs do. 2-5ths offhand men bargain work, putt'rs & boys					
	29,000 underground 7,624 above ground about pits	29,000 7,624				
	36,624 total at pits. Requires 18,500 at offshoots at a distance from pits to make up Mr. Hunt's Statistical Account 55,124 - - - - -	*36,624 18,500				
A	£13,000,000	55,124	15,500,000	15,500,000	..	5,940,666
No. 2.	Cumberland - - - -	See observation in No. 1 for workpeople.	887,000	....	..	....
	Yorkshire - - - -		7,260,500	....	..	....
	Derbyshire - - - -		2,466,696	....	..	....
	Nottinghamshire - -		813,474	...	..	....
	Warwickshire - - -		255,000	....	..	....
	Leicestershire - - -		439,000	....	..	....
	Half Worcestershire, & half Staffordshire -		3,750,000	....	..	....
B	£10,000,000	55,124	15,811,670	15,811,670	at 5s8d	4,477,888
No. 3.	½ Worcestershire and ½ Staffordshire - -	See observation in No. 1 for workpeople.	3,750,000	....	..	....
	Lancashire - - - -		9,080,500	...	..	....
	Cheshire - - - - -		786,500	....	..	....
	Shropshire - - - -		1,080,000	....	..	....
	Gloucestershire, Somerset and Devon - -		1,492,366	....	..	....
C	£10,000,000	55,124	16,389,310	16,389,316	at 5s8d	4,643,686
No. 4 N. & S. Wales.	Flintshire, Derbyshire, and Anglesea - -	See observation in No. 1 for workpeople.	1,143,000	....	..	....
	Monmouthshire, Glamorganshire, and Pembrokeshire - -		8,500,000	....	..	....
	SCOTLAND - - - -		7,448,000	....	..	....
	IRELAND - - - -		148,750	....	..	....
D	£11,000,000	55,124	17,239,750	17,239,750	at 5s8d	4,906,600
Total	£44,000,000	220,496	64,739,789	64,739,789	say	20 millions

* This number of 36,624 workpeople for above and below ground operations, is ample for the thin seams of Durham and Northumberland. In districts where the thick coal beds are worked, a considerably less proportion of above, as well as underground workmen, must necessarily be required at the pits, in consequence of a large proportion of the coals being used in the immediate district.

The 18,500 "Offshoot Men," to make up the quantity stated by Mr. Hunt, appears to me too high for either thick or thin beds in any district for the quantity worked or sold.

No. 5 E. ABSTRACT OF No. 1 A, 2 B, 3 C, and 4 D, Including further items of Capital for Shipping, Public Railways, Canals, and extra Charges; also Nos. 6 and 7 Tables of Capital and Mineral Production.

	Abstract E.	Capital.	Total Quantity in each district.	YEARLY. Millions Sterling.	YEARLY. Total.
	Abstract of 1 A, 2 B, 3 C, 4 D. (& 6 & 7 F & G below.)				for ores & iron
No. 1.	Durham & Northumberland - -	13000000	15500000	..	£5940666
	Shipping Capital from Durham & Northumberland Coast or Ports -	10000000	Freights on 8½ million tons.	..	5650000
	Share Public Rail, distance from 12 to 40 miles only-	6000000	4 p. c. for dues on Interest.	..	240000
			Do. Haulage.		240000
A	.....	29000000	15500000	..	£12070666
No. 2.	Brought over Capital - - -	10000000	....	4½ millns.	
	Public Rails., say -	5000000	....	} say 1	
	Canals & Shipping	5000000	....	} milln.	
B	.....	20000000	15811670	..	5477888
No. 3.	Brought over Capital - - -	10000000	....	4½ millns.	
	Public Rails., say -	5000000	....	} 1 milln	
	Canals & Shipping	5000000	....	}	
C	.....	20000000	16389316	..	5643689
No. 4.	Brought over Capital - - -	11000000	....	4¾ millns.	
	Public Rails., say -	5000000	....	} 1 milln	
	Canals & Shipping	5000000	....	}	
D	.....	21000000	17239750	..	5904595
1 2 3 & 4	Total for Coal - -	90000000	64,739,789	..	£29096835
No. 6, F	Mineral produce -	22000000	} See particulars	..	14607022
No. 7, G	Malleable Iron -	10000000	} below.	..	9003500
	Sundries - - -	10000000	13,362,000		....
	Totals ..	132000000	78101789 tons	..	£52747357

ABSTRACT No. 6 F.

Including Mineral Ore production and Malleable Iron.

F	Total average for each district workpeople	Total quantity of Tons in each.	Direct Capital	Capital, Public Railways, Shipping and Canals.		Total of Capitals	Total Value.
	£		£	£	£	£	£
No.1,A	55124	15500000	13000000	6000000	10000000	29000000	12070666
No.2,B	55124	15811670	10000000	5000000	5000000	20000000	5477888
No.3,C	55124	16389316	10000000	5000000	5000000	20000000	5643686
No.4,D	55124	17239750	11000000	5000000	5000000	21000003	5904595
	220496	64940736	44000000	21000000	25000000	90000000	29096835
				Number of Workpeople.			
				Iron - - - - 26208			
				Copper - - 21109			
			See particulars below.	Tin - - - - 14941		£	
No.6,F	101181	12000000		Lead - - - 21749		22000000	14607022
				Zinc - - - - 174			
				Clays, say 17000			
				Total - 101181		£	
	12000	1362000	Do.	Malleableiron12,000		10000000	9003500
No.7,G				Sundries -		1000'000	....
	*333677	78104789	Totals ..		113,181	132000000	52707357

No. 7 G. Particulars of Capitals, Quantities, and Value of Ores, including No. of Workpeople and Tons of Malleable Iron estimated to be made.

Names of Districts and Capital.	Workpeople.	Capital.	Tons.	Yearly production of each district.	Total production of each district.
G No. 7.					
Mineral produce in Ores			Tons not known say 846,752	£	
Zinc - - - - - -	174 Number of Workpeople not known.	....		15,500	....
Sulphur Ore - - - -		....		506,000	....
Silver - - - - - -		....		192,500	....
Tin - - - - - -	14,941	....	5,763	690,000	....
Copper - - - -	21,109	....	13,642	1,229,807	....
Lead - - - - -	21,749	....	64,005	1,473,115	....
Iron in Pig - - - -	26,208	....	3,069,838	9,500,000	....
Cement—Clays, say -	17,000	....	8,000,000	1,000,000	....
	101,181	22,000,000	12000000	14,607,022	14,607,022
Pig Iron made into Malleable Iron.					
⅓ of the 3,069,838	12,000	10,000,000	1,362,000	....	....
equal to 1,362,000 at £6 12s 6d per ton extra	....	....	....	9,003,500	9,003,500
Sundries - - - -	....	10,000,000	....	....	....
Totals with Capital estimated - - - - -	113,181	42,000,000	13,362,000	23,610,522	23,610,522
The Capitals & Incomes, from coal and coke as above - - - - -	220,496	90,000,000	64,739,789	29,096,835	29,096,835
	*333,677	132,000,000	78,101,789	....	52,707,357
Grand Total..	As below say ⅔rd at pits ⅓rd at offshts.	132 millions of capital.	78 millions tons yearly	....	say 53 millions sterling yearly

TABULAR FORM H, SHOWING, UNDER SIX DIFFERENT HEADS, THE TOTAL EXPENDITURE FOR COAL AND OTHER MINERALS IN THE BRITISH ISLES.

In order to make the preceding tables more intelligible, I shall now give the total number of workpeople, quantities produced in tons, and total of capital employed in Durham, Northumberland, and the three other coal districts (B C and D), with particulars of capital for iron and other ores, thus showing at a glance the whole amount of capital and sales yearly of the British Isles. To make it still more intelligible I shall divide the total amount of proceeds from mineral sales in all those districts into six different columns, producing the same result, though in a somewhat different form.

Before doing so, however, I give a statement of the total number of workmen employed in the various coal, ore, and iron districts of the kingdom, arranged in the same manner as the Durham and Northumberland district, No. 1 A, for coals only, and No. 7 G, for iron and other ores.

DIVISION OF LABOUR.

Total number of workpeople		220,496
Allowing two-thirds for above and below ground operations at pits.....	146,496	
And one-third for offshoots at a distance	74,000	
		220,496

OR IN A DIFFERENT SHAPE.

Hewers or diggers of coal, in districts 1, 2, 3, and 4	62,000
Safety staff, with boys, do. do.	18,800
Offhand men, putters, and boys, do. do.	35,200
Above ground, do. do.	30,496
	146,496
Offshoots at a distance for 1, 2, 3, and 4	74,000
Ores, &c., as given in No. 7 G.	113,181
Total workmen	*337,677

On the following pages I give two tabular forms, differing from the former ones.

* Two-thirds at coal pits, various ore mines, &c., with one-third at offshoots.

No. 1. A. WORKPEOPLE.

			£
....	15,500	ewers in Pits	775,000
3,300 } 1,400 }	4,700	Safety Staffmen and Boys	175,000
1,200 } 7,600 }	8,800	Offhandmen, Bargain work, Putters, and Boys	350,000
	7,624	above ground	300,000
	36,624	Durham & Northumberld.	1,600,000
	*18,500	Offshoots to make up Mr. Hunt's statistical account in No. 1	*800,000
See below, B C and D, same as A 1 above			2,400,000

GRAND TOTAL, WORKMEN, CAPITAL, QUANTITIES, AND COST.

TABULAR FORM H.

		Capital embarked	Quantity of tons sold yearly.	1 Cost of the Workpeople.	2 Cost, Agency, & materials.	3 Rents.	4 Interest on Direct Capital.	5 Leading.	6 Shipping.	Totals Yearly.
		£	Tons.	No.	£	£	£	£	£	£
55,124	(No. 1 A)	29,000,000	15,500,000	2,400,000	1,125,050	387,500	1,125,000	1,383,116	5,650,000	12,070,666
55,124	see observation No. 1 above. (2 B)	20,000,000	15,811,670	2,400,000	932,598	395,290	750,000	480,000	520,000	5,477,888
55,124	Do. (3 C)	20,000,000	16,389,316	2,400,000	1,083,954	409,732	750,000	480,000	520,000	5,643,686
55,124	Do. (4 D)	21,000,000	17,239,750	2,400,000	1,248,595	431,000	825,000	480,000	520,000	5,904,595
220,496	220,496	90,000,000	64,940,736	9,600,000	4,415,197	1,623,522	3,450,000	2,823,116	7,210,000	29,096,835
101,181 } 12,000 }	113,181 (6 & 7)	22,000,000	12,000,000	4,400,000	5,957,022	1,000,000	2,750,000	250,000	250,000	14,607,022
	(F&G)	10,000,000	1,392,000	660,000	6,953,500	290,000	1,000,000	50,000	50,000	9,003,500
	*Sundries (0)	10,000,000	....	....	....	....	....	....	....	....
333,677	2-3rds at Pits ..... 1-3rd offshoots at distance	132,000,000	78,302,736	14,660,000	17,300,719	2,913,522	7,200,000	3,123,116	7,510,000	52,707,357
Or without leading & shipping		76,000,000	78,302,736	14,660,000	17,300,719	2,913,522	7,200,000	....	....	42,074,241

I think I may very justly say that the cost of labour amounts to about fifty per cent of the whole cost of production. But in order to make this more explicit, it will be well to show the relative proportion of expenditure for direct labour to the total sum paid yearly by the producers for the various other operations connected with the trade. For that purpose I annex the following table:—

DIVISION OF EXPENDITURE.

DIVIDED UNDER SIX DIFFERENT HEADS, INCLUDING VALUE OF COAL, ORES, AND IRON.

		Tons.	£	£
No. 1.	Paid for Workpeople, direct	78,101,789	14,660,000	
No. 2.	Agency and Material		17,300,719	
No. 3.	Rents		2,913,522	
No. 4.	Interest		7,200,000	
				42,074,241
No. 5.	Leading		3,123,116	
No. 6.	Shipping		7,510,000	
				10,632,116
				52,707,357

From these statistics it will be observed that the direct cost of labour is only £14,660,000, but it must not be forgotten that the other heads of expenditure necessitate the employment of labour to a very considerable extent; as, for instance, agency, which, although it cannot justly be termed direct labour in the same manner as that phrase is applied to manual operations in connection with mines, is, nevertheless, an indirect employment of labour, and as such, necessitates a large expenditure. Materials, also, in being prepared and adapted to the proper situation intended, are largely connected with labour, say about forty per cent. of the total produce, for that item. Another item, which, although not in rotation, includes the next largest amount of labour, is Leading (No. 5), the labour connected with which may be taken at about thirty per cent. of the whole expenditure for that item. The proportion of labour employed in the collection of rents and interest* is very trifling compared with the other items, and considering that the amount placed to those two accounts is nearly equal to two-thirds of that required for agency and materials. Thus, taking in shipping, which includes labour for freights, agency, &c., we arrive at something like the sum stated above, namely fifty per cent. upon the whole expenditure.

* The rents are put down at a fair computation, and represent the sums actually to be paid by the lessee to the lessor, even supposing the former loses by the concern. The interest accruing to the lessee, or speculator in mines, at the present time, I have put down at thirty-three per cent. higher than I believe has been the average for the last twenty-eight years. It will be seen that I put down 10 millions out of 132 millions capital paying no interest whatever.

I think it will be conceded, on a careful perusal of the foregoing statements, that they afford a fair comparison of the capital, quantity, and cost of production of coal and other minerals in the United Kingdom.

My own conviction, derived from the intimate knowledge I possess, not only of the various mining districts of this, but also of foreign countries, is, that the large capital which, for the last twenty-eight years, has been embarked in mining operations, public railways, and shipping, has not realized more profit than if it had during the same period been invested in the funds, or upon real estate, producing with safety from three and a half to five per cent. In fact, when we consider the deterioration of the plant and working stock of mining property, the immense losses which have been involved by the partial if not complete failure of numerous speculations on an extensive scale, and the vexations and disappointments connected with others, it would appear that the latter course, namely, that of investment, would have been more advantageous, and attended with more safe and certain benefit to speculators. There is, however, this redeeming feature in the case, that the working population of this country, instead of being now in a similar position with respect to low-priced labour† as those of Austria and other continental countries, or what England was in the thirteenth century, are, by the embarkation of such large capital, receiving 360 per cent. more than is paid in those countries, or say ten times the amount paid in England at the period alluded to. I am also bound to say, that had only one half of the vast sums embarked in these undertakings been invested in this way, the consequences might have been that only a very moderate interest would have been obtainable by such extra capital having been put into those other securities, probably one half only of the rates hitherto obtainable. But on the other hand, the other moiety embarked in speculative concerns, would, doubtless, have realized more than double the amount it has done during the period referred to.

† It will be hereafter shown that able-bodied workmen are working in Austria for 10d. per day, whereas the wages paid for the same sort of labour in England average from three to five shillings per day. Taking the majority of continental countries the difference of wage for labour is probably 300 per cent. in favour of the working man in England, or about as 1s. 0d. is to 4s. 0d. According to the statement of M. Jars, in his "Voyages Métallurgiques," the daily wage of a Styrian miner in 1758, nearly a century ago, was 11½ kreuzters, equal to about 5d., per day. At the same period the wages of the English miner were about 1s. 4d. per day. By this it will be seen, that while wages in this country have advanced 66 per cent. within the century, in Austria they have only advanced fifty per cent. during the same time. Even at the period mentioned by M. Jars, it will be seen that we were paying 200 per cent. more for wages per diem than Austria, whilst at the present date we pay 380 per cent. more. I must, however, admit that English labour is more effective. At the time of my visit the rate of exchange was fully twenty-three per cent. in favour of English money.

TABULAR FORM I.

The accompanying Table will show more clearly the Yearly Amounts set forth in the previous one, and alluded to above.

Nos.		Capital.	Materials.	Rent, Interest, &c.	Totals.
		£	£	£	£
1	The Amount paid for Labour, per Annum	14,660,000	.....	.....	14,660,000
2	Labour and Law Charges, Ditto	6,000,719	.....	.....	.....
	Agency Ditto	299,281	.....	.....	17,300,719
	Materials Ditto	.....	11,000,719	.....	.....
3	Rents to Landlords, Government Tax, Agency, and Law Charges	391,300	.....	2,522,222	2,913,522
4	Interest on Capital, Government Tax, Agency, Law Charges, & Risk	1,180,000	.....	6,020,000	7,200,000
5	Railway Leading, Labour, say Interest, Do. Agency, & Law Charges	1,000,000	623,116	1,500,000	3,123,116
6	Shipping, divided into Three Heads, say Labour and Law Charges, Materials, and Interest	2,500,000	2,500,000	2,510,000	7,510,000
		26,031,300 or 50 per Cent. p.a.	14,123,835	12,552,222	52,707,357

Divided into Three Heads, thus:

Showing—Total, Labour 50 per Cent. per Annum .. .. .. 50 per Cent. £26,031,300

„ Materials 26 per Cent. Ditto .. .. 50 per Cent. £14,123,835

„ Rent, Interest, Tax, and Law Charges, 24 per Cent. Ditto 12,552,222

100 26,675,057

Total Yearly Expenditure 52,707,357

DESCRIPTION OF THE COAL MINES AT BUCHBERG, *&c.*,

IN THE CIRCLE OF CILLI, DUCHY OF STYRIA, AUSTRIAN DOMINIONS, THE PROPERTY OF JOS. L. HAUSMANN.

1. WHERE SITUATED.—On referring to the accompanying plan marked No. 1, it will be seen that the coal mines and mineral concessions forming the subject of this description are situated in Styria, in the Austrian dominions, near the town of Cilli or Zilli, in the circle of that name, on the great trunk line of railway from Vienna to Trieste, and about latitude 46° 15′ north, and longitude 15° 18′ east from Greenwich.

2. NUMBER AND POSITION OF THE COAL MINES.—The mines consist of twelve distinct drifts, with horizontal shafts cut through the rock into the coal seams. Those drifts occur on three separate blocks of land with the beds or seams of coal lying the same way, as will be seen on plan No. 2, denoted by a *red line*, while the position of the workings is marked with *blue dots*. Ten of them are opened at Buchberg, a distance of from six to seven miles by the present road from the town of Cilli, one at Petschounig, about one and a quarter miles distant, and another at Riffingost, about three miles from the same town by road and railway. Besides these twelve mines in actual operation and producing *saleable coal*, there are twelve other drifts into the Buchberg seams at Schönstein, eighteen miles from Cilli, belonging to this property, where coal has been found, but not yet worked. These are marked on plan No. 2, by *crimson dots*, the *vermillion* dots denoting the positions of government and other proprietors' mines. It may not be amiss to state here, that the seams of coal in this locality are not near so numerous, nor, as far as I saw, so far below the surface as those of the adjoining kingdom of Prussia. In the coal districts of the latter country, (as is also partially the case in some of the Welsh coal districts, where the carboniferous stratification amounts to treble the thickness we have in Durham and Northumberland), the same seams may be passed four or five times in the course

of sinking a pit. The uniformity of the seam, with intervening strata in its proper place, is similar. On the accompanying plates the different inclinations of the seams are shewn; Plate 3 A, shewing the Prussian and Welsh seams, those in Wales I have not inspected of late, but they were described to me as lying in the position described in the sketch, the top of the seam in fact, becoming the bottom, by J. J. Atkinson, Esq., Government Mining Engineer; and Plates 3 and 8 give a fair idea of those of Austria. It may not be amiss to add, for further information, that Plate 3 A gives, also, to a certain extent, a correct representation of the seams in some parts of Belgium and France, which lie in the same way as those of Prussia.

4. Concessions.—These several drifts or horizontal shafts are driven into certain so-called concessions of land granted by the government to the proprietor. Each concession is a block of land 224 klafters or Austrian fathoms (a fraction more than an English fathom) long, by 56 klafters wide and 100 klafters in depth. For the better understanding of the tenure upon which these concessions are held, it may be necessary to state that the course adopted in this district is similar to that adopted in Prussia, viz., the government allows to each discoverer of a seam or any number of seams above or below such seam, the privilege of perpetual holding and working on payment of a certain portion of the sales. He is also permitted to hold any number of concessions, if after proving the same he may signify his wish to do so, by getting the same entered properly in the books belonging Government, kept for the purpose. Indeed, it is absolutely necessary that he should obtain a considerable number of grants, many thousands even, if he would hold collieries as large as ours in England. The concessions are of two kinds—1st, a lehen, or registered concession granted in perpetuity to the holder upon payment of about what would be called in England a tithe; 2nd, a müthung, or provisional concession granted to any party who proves to the Government Inspector of Mines that indications of mineral deposits have been discovered, such party having the option of abandoning the concession or confirming it into a lehen.

4. Lehens.—The twelve mines in operation hereinafter alluded to, and marked with blue dots upon plan No. 2, are driven into registered concessions or lehens. They are named and situated as follows:—

2 at Buchberg named Antoni-di-Padua (double lehen).
1 „ „ „ Theresia, No. 1.
1 „ „ „ Unterben.
1 „ „ „ Inatzi or Ignatius.
1 „ „ „ Ludwig.
1 „ „ „ Theresia, No. 2.
1 „ „ „ Edward.
1 „ „ „ Wilhelm.
2 „ „ „ Francesca (double lehen).
1 „ „ „ Adolph.
1 Petschounig „ Daniel Stattin.
1 Riffingost, (name not known). [illegible]

Total....14 Registered Concessions or Lehens.

5. MUTHUNGS (GERMAN, MÜTHUNGEN).—Of these there are twelve upon which coal has been found, and ready to be confirmed into lehens. (*See Plate* 4.) Their situations and names are as follows:—

1 at Buchberg, near the Ignatzi Lehen, named Lutzea.
1 „ „ Ludwig „ „ Montezzi.
1 „ „ „ „ „ Joseph.
1 „ „ „ „ „ Francesca.
1 „ „ „ „ „ [illegible]
1 at Schonston, without names „ „ [illegible]
1 „ „ „ „ „ [illegible]
1 „ „ „ „ „ [illegible]
1 „ „ „ „ „ [illegible]
1 at different places, ditto „ „ [illegible]
1 „ „ „ „ „ [illegible]
1 „ New Succession „ „ [illegible]

Total 12 Muthungs, or with the 14 above—26.

6.—GENERAL CHARACTER OF THE FORMATION AND WORKINGS.

The coal measures at Buchberg are below one block of land, upon hilly ground, about one English mile from east to west, and three-quarters of a mile from north to south. Three seams of coal have been bored into, through three layers of rock, two of them being much alike in thickness, and lying at much the same angles as in the subjoined section (*Plate* 3).

The layers, or coal seams, are found of good workable thickness, some above and some a short distance below the base of various conical, sugar-loaf-shaped mountains. The upper formation consists of drift or till. The second, called grey rock, is of an immense weight. The stratification between mountain and mountain is cut off by the valleys intervening, therefore, it may hereafter press with immense force upon the vacuum created by the abstraction of part or all of the coal, and thus cause greater

risk in the working of the mines. In the mines I visited, the superincumbent matter had not affected the working drifts which were then open, although the pillars were only left of a slight thickness.

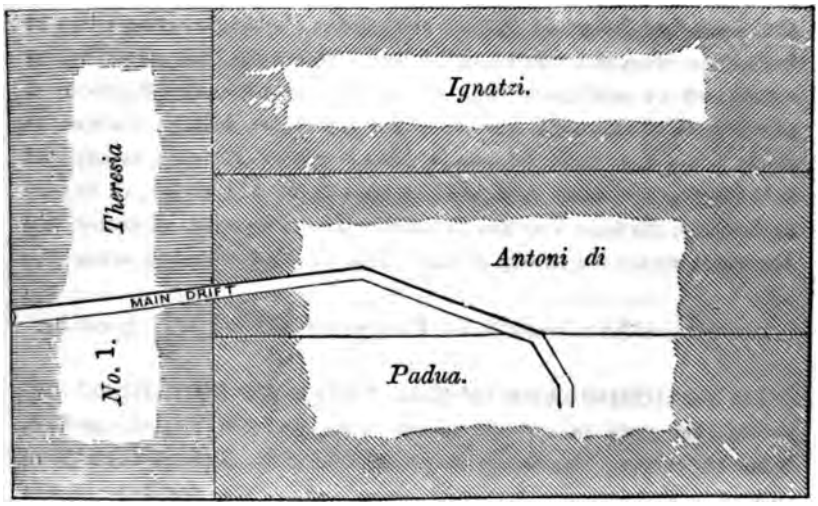
The upper and second strata are soft and friable, and, when cut into require to be propped up with posts and boards to prevent them falling in. This, however, is not necessary in driving a level through the third stratum, as it becomes sufficiently hard to support the superincumbent pressure. These general features of the Buchberg seams apply to those at Petschounig. The Lehen at Riffingost and the Provisional Concessions at Schönstein were not examined by me. The mines in operation are all entered by adit levels from the surface, and branch off into horizontal drifts through the grey rock, and sometimes through the coal, as shown in the foregoing plate, and with one trifling exception, as indicated in drift No. 2. These drifts are from five to seven feet high, six to nine feet wide at the base, and five to six feet at the top, and are sufficiently ventilated without artificial means. The workings average seven feet high by six feet wide, and are free from dangerous gases, so that the miners are enabled to work by the light of an ordinary lamp or candle.

7.—PARTICULARS OF THE MINES AT BUCHBERG.

The first mine in the hill, on the plan No. 2, is named the Wilhelm Concession. Entering the drift, which opens from the side of the hill, it continues in a straight southerly direction for a distance of fifty-three klafters or fathoms. At this point it strikes off at a right angle eastward for a short distance, where the coal has been worked for some distance in the upper seam, which dips to the north at an angle of eleven degrees. The drifts of this seam are seven feet high, and six feet wide, through *solid, clean coal*, with a floor and ceiling of coal, which appears firm. From here the adit levels have been driven through the second stratum of grey rock into the middle seam of coal, which is of better quality and still greater thickness than the upper seam (*See Plate* 3). The Mining Captain states that he considers it on an average fourteen feet thick. The excavations here are from six to seven feet wide, and from seven to eight feet high, with three feet above and below unworked, all of which are sound good coal, without any slate or clay intervening between the outer surface of the seam and the strata of rock. About the middle part of this concession, and at the extreme point of the workings, the grey rock begins to thin-out, and the upper

and middle seams are calculated to unite, within a few yards, to a thickness of twenty-four feet, as is seen in one of the adjacent coal mines belonging to other proprietors.

The next mine which has been worked to any considerable extent is in the concession named Antonio-di-Padua—a double Lehen—which, with the concessions Theresia No. 1, and Ignatzi, form a block of land, or coal mine, thus,—



This mine is entered by a level drift driven into the grey rock, between the upper and middle seams, for a distance of twenty-five klafters or fathoms through the No. 1 Theresia concession, to the top of a square shaft sunk vertically for fifteen feet, at the bottom of which several levels branch off at angles into the middle seam, as shown at *B* in *Plate* 3, and in the above diagram. The drifts through the seam are six feet wide, and seven feet high, with walls, floor, and ceiling of sound, solid coal, the bed lying at an angle of fourteen degrees.

Near this block is the Müthung, or provisional concession called Lutzea, which promises to become, when drifted further, a good seam of coal, from the indications of the grey rock and other strata having a drier and harder consistence. Further to the south-east are the Theresia No. 2 and Ludwig concessions, both lehens entering from one main drift and then branching off. In the latter mine, as in the Wilhelm, the miners expect the two upper seams to join. As yet the lower or third seam has

not been worked. In the vicinity of these are five müthungs, where coal has been come upon, and which being ready, will, when the government certificate is obtained and registered, become lehens.

Crossing a small stream at the highest point of the workings on the Buchberg hills, near the outer drift of the lehen, Theresia No. 2, in a south-west direction, is the Edward coal mine, the first opened at Buchberg, which has been worked for ten years. Here the workings are driven into the middle seam, lying at an angle of forty-four degrees. On account of this great dip, and the water collected in it, the mine has been left unworked for two years, but the miners are again at work with a rude pump, draining the water out at the lowest drift, with the intention of driving a shaft from thence into the Joseph mine, at a level where the water would find an outlet, and enable them to excavate the bed of coal between the *two* mines, computed at an area of 10,000 square klafters or fathoms, through the middle seam. The concessions Unterben and Francesca on the list belong to this group, but they were not inspected.

8.—THE COAL MINES AT PETSCHOUNIG, RIFFINGOST, AND SCHONSTEIN.

The Daniel Stettin mine at Petschounig is entered by the usual level drift, through the grey rock, at the foot of a considerable hill. Its position is shown on plan No. 2, by a square blue dot. The adit level here is driven through the first and second seams, and the three strata of rock, all lying at an angle of forty-five degrees, with a north-easterly dip, into the third seam of coal, which promises to be the best in quality. The position and character of the strata show that it is a section of the same coal-field to which the Buchberg mines belong. The specimens obtained are much the same as the coal at Riffingost, but at Schönstein a difference in quality of a better character is shown. As these, however, are only provisional concessions, without having been worked, the particulars are not of so much importance.

9.—QUALITY OF THE COAL.

The three seams of coal described vary very little in quality, and cannot be considered a species of anthracite coal, although rather similar in appearance, from its cleanliness and the smallness of its flame, to that kind of coal, which may be distinguished from Newcastle by its having less bituminous properties. When touched it does not soil the fingers, and it burns, with very little flame or smoke, into a very moderate pro-

portion of reddish grey ash, (but with less slaty substance than is usually found in even the anthracite coal in Pennsylvania, United States of America), and about the same quantity, but with much less flame, than the bituminous cannel, or the good splinty coal in England.

This Austrian coal, however, produces no cinder. It is not so suitable for house use, nor yet so strong or powerful for steam engines or other purposes as English or Welsh steam-coal. The upper seam is the lightest in specific gravity and the most friable, while the lower seam appears to be not only more compact and heavier than the other two but possessed of greater bituminous properties. Its mineralogical character varies from a slaty structure with a cross cleavage, to compact masses having a large conchoidal fracture. It is a coal far less adapted for ordinary household purposes, than even the ordinary kinds of English, Scotch, or Welsh coal, but is, nevertheless, a good kind of fuel for steam engines, furnaces, smelting works, &c. (*See Appendix*,—Dr. Richardson and Mr. Browell's analysation).

10.—ESTIMATED QUANTITY AND PROBABLE DURATION OF THE COAL FIELD.

As already stated, a concession is 224 klafters or fathoms long, by 56 klafters wide, giving a superficies, calculating the klafters at four square yards, of 50,176 square yards. Say that twenty feet of coal in depth is worked over the area of each concession, this would give the contents of one at 150,528 cubic feet, equal to 90,318 tons (calculating the ton even at fifty cubic feet), and that the twenty-five concessions would yield, on an average, as much as they at present indicate (allowing as above for risk or unworked coal), it will be found that the whole area of the Buchberg mines alone would produce 2,257,950 tons. Hence, if worked at the rate of 20,000 tons annually, there would be coal sufficient to keep the mines in active operation for about a century, or, at double that rate, half a century. I see no good reason to stop at 20,000 tons per annum when sales are profitable.

11.—ESTIMATE OF THE QUANTITY ALREADY PRODUCED.

Although these coal mines have been opened at intervals during the last nine years, each mine yielding more or less from the time of opening, yet the total quantity which has been produced from them does not exceed 5,220 tons. The proprietor has spent his means and applied his labour in driving levels into the concessions, for the purpose of securing

them as fully registered lehens, leaving it for others, by means of future operations, to work them out fairly. This gentleman, it appears to me, finds himself unable at present, from want of capital and various causes unnecessary here to mention, to continue even these preliminary operations to the desired extent, and, consequently, he has offered the mines and other property for sale, but has not yet met with a purchaser. In case of peace, however, between the contending powers, a much better chance may be afforded him of realising his intentions, and, particularly, when the railway from Vienna to Trieste, which passes near to this property, has been completed, and such may be the case within a few months from this date. The greatest quantity worked out in one year was 1,600 tons in 1852, and the annual produce since they were commenced has been 580 tons. This trifling result arises not only from the want of capital, but from various other causes; however, railroads coming so near as only to require five or six miles of light railway to carry carriages laden with from half to a ton or more of coal, would very much cheapen the transit from these mines either to the railway at Cilli and thence to Laibach and Trieste, or reverse way to Vienna and other places (*see Plates* 1, 2, *and* 8). The excavations through the rock are in extent equal, if not greater, than those through the coal seams, the labour so expended yielding no immediate return, while the number of men employed is regulated by the income derived from the small quantity of coal sold. Besides, the means and appliances of the workmen are altogether inefficient. Nothing but hand-labour has been employed, and there is not a piece of machinery, beyond a rudely constructed pump and a windlass, worked by hand, in the whole of the workings, yet in some other coal districts they have got more means, as horses, and oxen, and even steam engines applied to some pits.

12.—COST OF PRODUCTION, CARRIAGE, &c., AND THE SELLING PRICES.

The cost of producing the coal is at present 1s. 10d. per ton at the pit's mouth, the government dues scarcely amounting to one penny per ton. Something like a tithe, or tenth of the sales at the pit, is, however, understood to be due, but the government surveyor hitherto has taken only a small sum annually for the dues, without looking into the produce book. The carriage from Buchberg to the nearest market town, Cilli, is by means of a rude description of waggon used in the country, drawn by horses or oxen. They have no fixed steam engines, nor, as yet

locomotive power; but with a very light rail, with light carriages, horses or fixed motive power might be employed *(see Plate 8)* for the above-mentioned five miles, on a portion of which a locomotive might be made to travel at a very trifling expenditure compared with the present cost of 4s. per ton, the distance by cart road at present being seven English miles. The road between the mines and the town, after passing through a valley and up a short hill, is down hill for the next two or three miles, over stony and soft ground, after which, on crossing a bridge over the Sann river, it is a level post road, kept in good repair all the way to the railway station at Cilli, a distance of four miles. The price obtained for the coal in Cilli, and at a spinning mill in the suburbs, is 13s. 9d. per ton. In both places the demand is greater than the supply, and they have not as yet any public depôt in either place. From Cilli to Laibach (fifty-four miles), the carriage is by railway, at 3s. 2d. per ton, and from Laibach to Trieste (sixty-six miles), where there is a great demand for coal, even by *waggon*, with horses or oxen, the charge is 38s. per ton, making a total cost at that seaport, of 47s. per ton. At all events, this was the price *in August*, 1854, at which time from 50s. to 60s. was easily obtainable at Trieste or Vienna. When the railway, now constructing between Laibach and Trieste, is finished, the carriage will be only 7s. 4d. per ton, reducing the cost price to 16s. 4d. per ton, thus allowing a marginal profit to the coal owner, at present rates, of at least 30s. to 40s. per ton. I here must not omit to shew what has been the cost of English coals, sold at Trieste and Venice, at different periods, and also the probability that, with screw steamers and ships, it may hereafter be still less.

13.—COST AND FREIGHT OF ENGLISH COAL IN AUSTRIA.

In 1852, the freights of ships to those places was from 18s. to 20s. per ton, the price of good coal in England being then 6s. 6d. to 7s. 6d.; thus averaging from 25s. to 27s. per ton.

In 1853, freights were 22s., 26s., 30s., and 33s. per ton, and coals the same price; the average cost being 35s. per ton.

In 1854, freights were 27s., 38s., 40s., 45s., and 59s., and coals a little higher. At the time I was at the above places, freights were 49s., and English coals 8s. 6d., making 57s. 6d. per ton.

In 1855, freights were 40s., 38s., 39s., 35s., 33s., 36s., and 37s. per ton, and coals say 7s. 6d.; average, 44s. 6d. per ton at Trieste.

From the numerous ships and screw steamers now employed in carrying

coals, particularly from Newcastle-upon-Tyne and the other ports on the German Ocean, and from the great number now building, together with those that will be thrown into the trade again when unemployed in the war department, freights may again become as low as ever they have been, and there is no doubt England could again supply coals at the same low prices as formerly; consequently, the freight and cost of coal might not exceed 25s. or 27s. per ton, as heretofore stated. At the same time, Austria will have her railways completed to Trieste, and may be able to reduce the price of her coals accordingly, if such a course be found necessary. Hitherto no coal has been sent from Cilli to Vienna on the railway over the Semmering Alpine Pass. Now, however, that this gigantic piece of railway engineering is completed, it is expected that a large trade will be done in the Austrian capital, where the price paid for Belgian coal in 1854 was 60s. per ton. At other inland places, too, where, no doubt, coals can be had at low prices, immense quantities will be used in lieu of the present fuel (wood).

14.—IRON TRADE IMPORTANT TO THE COAL TRADE IN ALL COUNTRIES.

Having thus shown you the various fluctuations of the coal trade during a given period, I trust I shall not be departing from the strict letter of my subject—having, in page 57, treated upon pig iron at some length—if I add a few remarks upon the state of the Styrian iron trade; the more so as the variations in price of the one product affect the other in no slight degree *(see Appendix A, Note 1)*. In the first place, I would remark on the insignificant quantity of iron produced annually in those dominions, notwithstanding that in some places the ores are placed so near the surface that the rock can be quarried in the open air. Even at the mountain containing the least inaccessible and most productive iron ores, the quantity realised is not more than 20,000 tons per annum; a quantity scarcely sufficient to serve our Government for a month of actual preparation for war, such as providing cannon balls, &c. Indeed, throughout all Austria the annual production does not exceed 220,000 tons, even in the best of seasons. The quality is, undoubtedly, superior, which is accounted for by the fact that it is mostly made with charcoal. From time immemorial it has occupied the foremost rank in this respect. I doubt, however, at the present day, with the improved systems in use amongst English manufacturers, that the position is tenable. By means

of improved and constantly improving machinery, and all those modern appliances of science and art, (more particularly the improved method, lately introduced into the trade, of mixing the various kinds of iron before and after smelting), the discovery and application of which have made this nation famous in the eyes of the whole world, we have shot far a-head of our competitors, and rendered it almost impossible for Styria, or indeed any other nation, to compete with us, for more reasons than the one given. In the first place, immense capital is required to work these mines to any advantageous extent, and of this important commodity, there is in Austria an alarming deficiency; and, in the second place, the unrivalled facilities afforded to English manufacturers by the cheapness of coal and limestone on the spot, as well as that of transit, both by land and sea, enabling us to carry iron into Austrian ports, and vend it there at a cheaper rate than the native manufacturers; if, indeed, the rates which they have hitherto paid be taken as a criterion.

For instance, we can carry pig metal as ballast, with other light merchandise, and after paying all expenses, sell it in those ports at an average rate of £3 12s. 6d. per ton. The native merchants hitherto, have not been in a position to afford to dispose of it at these prices; indeed the price charged, up to the present time, has been £5 per ton and upwards. No doubt, if they avail themselves of the facilities which railways and improved machinery afford, to produce the coal and iron ores as cheaply as they might do, they will be able to reduce this rate to some extent (not improbably to a price which would go far to exclude English competition), particularly in the interior of the Austrian dominions, where the iron and coal are difficult of access, and the rate of carriage from whence to the seaports is so very high. This result is, however, contingent upon their retaining and using their own iron in the latter district. In such case there would be less to send, and the quantity sent would, on account of the cost of transit, be considerably increased, and the price of native iron at the seaports would be considerably augmented, and English merchants would reap a proportionate advantage.

To further illustrate the great importance of the iron trade in certain localities, such as Durham and Northumberland, and indeed, throughout the British Isles, it only requires to be shown that about one-third of the 64½ million tons of coal brought to the surface of the earth in this country is applied to the working of iron into the various necessary forms. Therefore, 64½ million tons are lessened as follows:—

	TONS YEARLY.
For Scotland	5,400,000
„ Staffordshire	5,300,000
„ South Wales	5,050,000
„ Durham and Northumberland	*3,500,000
„ Derbyshire, Yorkshire, Cheshire, Shropshire, Flintshire, Lancashire, and Cumberland	2,500,000
	21,750,000
Tons left	42,989,789
Total	64,739,789

	TONS YEARLY.
*The produce of the Durham and Northumberland coal-field is	15,500,000
Less the above, for 80 furnaces making iron ..	*3,500,000
Leaving for other purposes	12,000,000

15.—RAILWAY CARRIAGE TO VIENNA AND TRIESTE.

A glance at the plan No. 1 will show that the chief value of these coal mines is their proximity to the great southern trunk line of railway (to which they might be connected by a light line of railway for tub carriages, as alluded to before), through the Austrian dominions, between Vienna and Trieste, a distance of 336 miles, and respectively 216 and 120 miles from Cilli. At this date (December, 1855), the line is completed and in full operation between Vienna and Laibach, a distance of 270 miles, and it is affirmed by the government engineers that the remaining 66 miles will be open for traffic on or about June 1856. This completed, there will be a *through* line of railway between Cilli and the principal seaport of the Austrian dominions, from whence it is confidently expected that there will be an unlimited export trade in coal, for the supply of steam vessels, to the stations in the Mediterranean and Black Sea (and it necessarily must follow that a number of other manufactories, using an immense quantity of coal, will spring up). Besides this, it has been computed that if the Buchberg mines were worked, and the first year yielded only the small estimated quantity of 1500 to 2000 tons of coal per month, there would be sufficient consumption for it at Vienna. At present there is no coal depôt for native produce either there or at Cilli; that which is

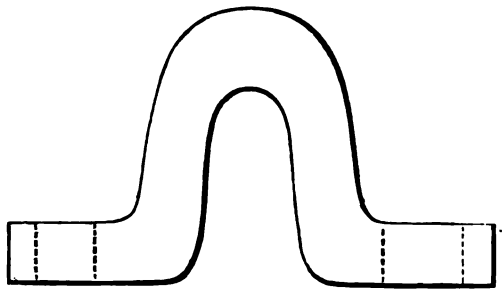
* To illustrate this subject still further, I may state that the Consett Iron Company, County of Durham, require for the production of iron, as many coals yearly as any of our largest collieries or coal companies produce during the same period.

brought to market is at once consumed, along with wood, the principal article of fuel in Austria for steam purposes and smelting furnaces. Should, then, a light railroad with part tramway be laid down between Buchberg and Cilli,† and a depôt be formed there, even supposing the annual production not to exceed the estimated quantity of 20,000 tons, it is calculated that the demand for the railway engines alone would equal the supply up and down the line. Such a railway, if constructed on the right bank of the Sann (*see Plan No.* 2), would lessen the distance between Cilli and the mines to five miles, and would carry the produce to market much cheaper, and in one-tenth the time it occupies at present. Subjoined is an end view of a full-sized rail, such as I think might answer the purpose, and be laid down at a comparatively small cost, viz., £200 per mile for double rail, and for labour—which in that locality is cheap, as is also timber, which may be obtained from off the mountains at little more than the cost

† Since the above was in type, I learn that the Austrian Government has ceded this railway to a private company, and it will now be to the interest of both parties to encourage, as much as possible, the investment of large capital in mining undertakings, whether by aliens or natives; this costly railway, forming a key to the whole country, connects the same with all the other continental railways, which, also, are of immense advantage to Austria. The chief promoter of these undertakings is Baron Bruck, the Minister of Finance, who is desirous of giving every advantage to capitalists to work out the resources of the country.

[The following from the *Oesterreichische Correspondenz* can hardly fail to be interesting in connection with this paper:—"A great gap in the Austrian railroad net is about to be filled up. His Majesty has granted to M. Ernest Merk, the Imperial Royal Consul at Hamburg, and to M. H. D. Lindheim, merchant, a privilege to construct a railroad from Vienna to Linz, and thence to the Bavarian frontier near Salzburg, on the one side, and to the Bavarian frontier near Passau on the other. The railroad, which is as important for Bavaria and Southern Germany as it is for Austria, will bear the name of 'the Empress Elizabeth Railroad.' The length of the railroad from Vienna to Salzburg is about 212 English miles, and from Linz to Passau 59 English miles. The period granted for the construction is five years. The plans for the line from Vienna to Salzburg are almost completed. The State, which makes the grant for 90 years, guarantees 52-10 per cent. for interest and amortization of the shares. The grantees intend to form a joint stock company with a capital of 65,000,000fls., and it is probable that the Austrian Credit Bank will be concerned in the undertaking. The Vienna-Salzburg Railroad will, of course, be continued to Munich, and an uninterrupted railway communication will be opened between the Atlantic and the Adriatic, and travellers will hardly be more than 36 hours on the road between Vienna and Paris. The new railroad will, however, be of infinitely more importance to the mercantile than to the travelling world, and this is why far more attention is paid by foreigners to this than to any other Austrian railroad. It is foreseen that the great mercantile road between Paris and Vienna must soon extend to the coasts of the Black Sea, and to the capital of the East (Constantinople). A most careful calculation shows that there is a movement of 2,000,000 travellers and 16,000,000 cwt. of goods in the valley of the Danube in the course of the year, and a total receipt of 8,500,000fl. This revenue alone would give a clear dividend of 8¼ per cent. on the capital after all expenses had been deducted."—The '*Times*' says that the Austrian Credit Bank has agreed to take to the amount of twenty million florins, and that the Rothschilds will be concerned to half that amount in the Elizabeth Railway. Several English firms had applied to Messrs. Merk and Lindheim for a share in the formation of this undertaking.—The formation of a great line of railway from Belgrade, on the Danube, in the Servian province of Turkey, to Constantinople, has been entrusted to one of the leading contracting houses of this country, but I am not, as yet, in possession of sufficient information to enable me to give the particulars.]

of felling and leading—say £200 or £300; in all, not exceeding £500 per mile, or £3,000 for the whole distance. The subjoined sketch represents



a rail, invented by Joseph Laycock, Esq., and improved by Mr. Robert Simpson, the manager of Towneley, Stella, and Ryton Collieries, and now in use at those places, the rollers for which were cut at Losh, Wilson, and Bell's Iron-works, at Walker. The weight of the rail is 13 lbs. per yard, or 26 lbs. per yard of double rail. Thus, at £9 per ton—the present price—the actual cost would fall short of £200 per mile, even for double malleable iron rails with pins.

16.—ESTIMATED COST OF WORKING THE MINES.

To work them by machinery or other motive power, by all modern appliances in the shape of implements, and by experienced miners, at an approximate calculation, would necessitate the following outlay:—

Say that it would cost £7,000 to form a railway, with other fixtures, between the mines and the station at Cilli, and £7,000 to put the mines into active working order, equal to any British coal mine producing 20,000 to 40,000 tons annually, it would require a further sum of £5,000 to erect the necessary buildings, and to meet contingencies, and £1,000 for inspection, thus involving an outlay of £20,000 before the mines could be put in full working order, besides the purchase money for the good-will, and the purchase of part houses, land, and timber. The latter could be effected cheap, which would make even the £20,000 an ample sum.

17.—GENERAL REMARKS ON THE FOREGOING.

There appears sufficient labour to be had on the spot, although it is a drawback to the country that the bulk of the able-bodied population, and that too, in the prime of life, when five years may be considered as fifteen

at the beginning or end of an average life, are taken away to serve as soldiers for so many years each, as a matter of duty. Able-bodied men will at present hire themselves for 10d. per day. Yet, if many coal pits and other establishments were underway, they would, in all probability increase the price of labour, for this part of the country is thinly peopled. The same may fairly be said to be the case throughout Styria and all Austria. However, these people are remarkably peaceable and docile, and, although slow in their movements compared with British labourers, who are now obtaining four or five times the amount of wages for the same occupation, yet the Styrian peasantry are proverbial for their industry and sobriety. The introduction of experienced overlookers and foreign capital into mining undertakings would be conferring a boon upon these poor people, and would be favourably viewed by the Austrian government, who, in such case, would, I consider, find it to their advantage to protect the interests of foreigners, who might invest capital in these dominions.

Although the quality of the coal, as herein specified, is considered inferior to Newcastle coal, on account of its small per centage of bituminous properties, and is less valuable than if it were a cinder or coke coal giving forth abundance of hydrogen gas, and that volume of heat which British coking coal produces,—and which, in August, 1854, sold at Trieste for sixty shillings per ton—still, if it realized on an average forty-five shillings per ton in that market, and, even if it cost, from England, or even Styria, twenty-five shillings instead of sixteen shillings and fourpence as estimated, there would be a clear nett profit of twenty shillings on every ton sold. It may, however, be remarked that the estimated yearly outlay stated is considerably above the mark, for in working these mines with level horizontal drifts instead of vertical shafts; with workable seams at convenient angles, and pretty close together, and with no fire or choke damp in them, the expenses for machinery and the employment of overlookers would probably not come to one half what it is at the Great North of England coal mines, where the seams of coal are of a much harder nature, and are situated many hundreds, nay, thousands of feet, below the surface, where dangerous gases are so apt to generate, requiring the constant use of the safety-lamp with gauze protector, and thus necessitating so much time, care, and attention, to watch over the lives of workpeople, as well as the expenditure of a large sum of money.

That the coal measures of this region extend and form kinds of basins is evident from other indications found in opposite directions to the Buchberg mines; and that they lie below the valley of the Sann is equally

probable, extending, in all likelihood, from Schönstein to Riffingost, and from Gosnik to Galizien, as seen on plan No. 2. Appearances seem to warrant the conjecture that this coalfield is very extensive and may last for many generations to come, as there seems every probability of coal being yet found at a lower depth than has yet been attained. Moreover, as iron, lead, and zinc ores are found in many parts of this district, *(see Plan No. 2)* several mines being now opened, and works erected, there will be a considerably larger local consumption of coal than there has been hitherto. Already large zinc mines are being worked, and large establishments are being erected for manufacturing the zinc near Schönstein, which I visited, as also the iron mines at Galizien, which are opened out extensively for inspection, and where drifts have been driven to great distances in iron ores, of most excellent quality *(see Appendix A)*. A couple of iron furnaces would consume the full amount of coal above the estimated yearly quantity, viz., four times twenty thousand tons, and Austria's own requirements for extra iron alone ought to far exceed such a small yearly extra quantity.

18.—MUTHUNGS OF IRON, LEAD, AND MERCURY.

Besides the above coal concessions, Herr Von Hausmann had, apparently, a right over ten provisional concessions, where ores of iron, *(See Appendix A, Note 1)*, lead, and mercury, have been discovered near Maria-Reig, St. Magdalena, Laurent, and Buchberg, which are shown by red dots on plate No. 2. These were not inspected by me. The ores appear good, and there is every reason to believe that they are to be found at the places mentioned. Some specimens shown me of the lead ores from Maria-Reig and Magdalena, were of the ordinary kinds of galena, or sulphuret of lead, not rich in silver, and in some degree resembling the lead produced at the W. B. mines at Allenheads. These, with specimens of the Buchberg coal, accompany this report, the names and other particulars of which will be found in Appendix A.

CONSTRUCTION OF GREAT SOUTHERN LINE OF RAILWAY.

Having now given you a correct statement of the condition of the Buchberg coal mines at the time of my visit, I should consider my paper incomplete, if, after having travelled over so large an extent of territory for a merely speculative purpose, I did not supply you with some additional information respecting the construction of the Great Southern line

of railway to which I have already alluded; and also the various lead, iron, zinc, and other ore mines, which I visited as well as the famous subterranean Grotto of Adelsberg, *(see Plates* 5, 5*a*, 6, 7, *and* 10, *also Appendix)*, and the extraordinary lake of Zirknitz *(see Plan* 1, *also Map of Austria)*. With respect to the railway, my own experience and observation, both in this and various other countries, justify me in saying that the district through which it passes presented some of the greatest engineering difficulties that have had to be overcome on any line in Europe.

The first great difficulty which stood in the way was the construction of gradients over the eastern flank of the Styrian Alps, which, at a point called the Semmering Pass, was originally 4,000 feet above the level of the sea. To avoid going over the summit of this portion of the mountain the engineer was compelled to cut a long tunnel at a height of 2,893 feet above the sea level, thereby reducing the gradients considerably, but still leaving an altitude of 3,515 feet to be attained, and this too in a distance of 12 miles, and without the assistance of stationary engines. For this purpose he laid down a zigzag line in the valley of the Schwarza, and by throwing massive viaducts above viaducts across deep ravines, and penetrating the mountain sides with long tunnels, he effected his object, though at the expense of adding more than one-third to the geographical distance; as, for instance, the Cloggnitz station *(see Plan* 1*)*, which is situated at an altitude of 1,378 feet above the sea level, and in a direct line only about nine English miles from the Pass, is, by the railway upwards of twelve miles. The steepest gradient upon this remarkable incline is 1 in 40, and not one is less than 1 in 100.* On the Vienna side the gradients are not so steep. The slope assumes no greater declination than 1 in 60, and as far as the Murzaischlog station *(see Plan* 1*)*, the line is tolerably straight. The whole distance between Cloggnitz and Murzaischlog station is more than twenty-five miles, of which upwards of two miles and a quarter is tunnelled through rocks, and for a distance of nearly a mile and a half the line traverses viaducts. The works were

* Similar gradients on locomotive lines are to be met with in England. For a short distance upon the Hartlepool line the gradient is 1 in 37½. On the Stockton and Darlington Railway there is an instance of 1 in 40. The proposed Union Railway between Stocksfield and Consett has an average inclination of 1 in 44, and the gradients of the tunnel on the South Wales Railway, at the approaches of Swansea, range from 1 in 50 to 1 in 52. The incline plane upon the bank between Redheugh and Gateshead has a gradient of 1 in 27. Engines with tenders, and stokers and drivers, are frequently run up this incline.

commenced in 1844, and continued to progress uninterruptedly till the revolutionary period of 1848, when internecine troubles caused them to be suspended. As soon, however, as the storms which then overshadowed the political horizon had in a measure passed away, they were resumed, and were ultimately completed in July, 1854. On the day the line was opened, I met the engineer, who is an Italian, and a gentleman of the highest attainments in his profession, at Vienna, and on the second day after, I travelled upon it from the latter city to Cilli. Some twenty-three or twenty-four years ago, Professor Reipl, a distinguished scholar, who had formerly filled the post of tutor to Napoleon Bonaparte's son, the Duke of Reichstadt, visited Hetton Colliery, accompanied by an assistant, for the purpose of getting information upon suitable gradients for locomotive engines to travel over; it being in contemplation at that time, to lay down a line of railway between Fieume, the principal sea-port in Austria for ships loading wood, and Vienna. About sixteen years ago I also was present, with Mr. T. Wood, then manager of Hetton Colliery, when an engineer from Austria, whose name I believe was Von Gerstner, and who is now an engineer in Russia, came to make similar enquiries, probably with a view to the construction of the identical line I have above described; and it has often occurred to me as being somewhat remarkable that I should likewise have been present at the opening of this same line of railway.

ADDITIONAL REMARKS.

The successful establishment of this railway across the Semmering Pass reflects the greatest credit upon the engineer who executed the plan, and upon the government who sanctioned it. Amongst the many great engineering works in this country, executed by our Stephensons and Brunels, there are none which can equal it in magnitude. Although as monuments of skill and science the Britannia Tubular Bridge over the Menai Straits, the High Level Bridge over the River Tyne at Newcastle; the very ingenious mode of crossing the Nile, in Egypt, on a pontoon with a double railway, both inside and on the top of the pontoon, and it must be borne in mind, that the Nile, though not a tidal river, has a small but constant daily variation, its extreme change of level amounting to twenty-six feet at certain seasons of the year; and the Thames Tunnel, which could only have been successfully carried out by the untiring perseverance and indomitable courage of a Brunel, aided by those ample resources, which, regardless of expense or prospective gain, are ever at

the command of Englishmen in cases of difficulty and danger, will ever rank among the wonders of the age, yet, it is no exaggeration to state, that this piece of engineering is as noble in design and as wonderful in execution as any of the above stupendous undertakings. Those who have crossed the Grampian Hills in Scotland, or travelled thirty miles over the highest mountain range in Wales, or the Alleghany Blue Ridge of mountains, near Charlesville, in the United States, will form some conception of its magnitude, if they can imagine themselves taking a journey over these heights on the smooth lines of a railway, or what is not a far-fetched comparison, able to cross Skiddaw in a couple of hours.

THE CAVERNOUS REGIONS OF CARRIOLA—ADDITIONAL ENGINEERING DIFFICULTIES.

The remaining engineering difficulties on this line lie in the Province of Carriola, where the nature of the country presents obstacles probably more insurmountable, though not so grand, as those of the Semmering Pass. This portion of the line when I visited it in August, 1854, had been carried to a distance of 306 miles, viz., from Vienna to Laibach, leaving 60 miles, the distance from the latter place to Trieste harbour, to be completed as shown by a strong dotted line on Plan 1.

To understand the precise nature of these difficulties, a slight sketch of the geology of this extraordinary region will be necessary. The upper crust or surface consists of an unusually chalky granular limestone, belonging to the secondary formation. During our journey towards Trieste we first came upon this rock up the Valley of the Sann, and traced it towards Mount Terglon, the chief of the stupendous Alps. In fact, that mountain, though 13,000 feet high, is of the same kind of rock, and abounds in natural caves and tunnels. This formation encloses beds of cinnabar or sulphuret of mercury, ores of lead, manganese, zinc, and other metals. It is here, in a valley on the western slopes of the mountain range, about twenty miles from the village of Upper Laibach, that the celebrated quicksilver mines of Idria are situated, and, also, the extraordinary Lake of Zirknitz (*see Plan* 1), five miles long, three miles broad, and fifty feet deep, which disappears for weeks, sometimes months, and in one instance was not seen for a whole year. During its absence, the people who inhabit the numerous villages and castles on its borders, sow grass and buck wheat in its bed, and frequently reap their crop before the waters flow again through the funnel-shaped fissures. Here, also, is the grotto of Adelsberg, the most extensive and magnificent cavern in Europe, which may

be explored for upwards of two miles through vast natural chambers and passages, one of the former being a hundred feet high, and three hundred feet long, and hung with the most beautiful fret-work of stalactites, which, by uniting sometimes with the stalagmites, form gothic-looking alabaster columns *(See Plates* 5, 5*a*, 6, 7, *and* 10*)*. Through this cavernous region many rivers pursue an underground course, rushing from the light of day into dark caves, where they flow onward for miles, and may be seen again issuing from the sides of mountains like rivers without a source. It is a region of subterranean wonders, differing in every respect from the mines and caverns formed by the hand of man. During a dreary journey of thirty miles from halfway from Laibach to Trieste, we beheld nothing but dismal crags, covered with a scanty vegetation, whilst beneath our feet were caverns filled with wonders innumerable—romantic lakes, roaring waterfalls, and rapid rivers.

It is over this extraordinary region that the Austrian Government are constructing the continuation of the great southern railway towards Trieste, which, when finished, will be of so much service to those who bring the Styrian coal mines into operation. The difficulties to contend with are unusual, for the engineer has to select that part of the country which is of the most solid formation, otherwise the weight of heavy trains passing over a thinner crust than usual, might precipitate the carriages into some dreadful cavern. It may have been to obviate the occurrence of such a catastrophe that the engineers have been so long in constructing the line. If I am not in error, it was commenced upwards of thirteen years ago, and is not yet quite finished (December, 1855). Should the government conclude their arrangements with the New Bank of Credit at Vienna, or a company with whom they are in treaty, regarding the concession of this line,* there is every probability of its being finished next year, which will conclude the extension of the Austrian line of railway from Vienna to Trieste, a distance of 366 miles, or to take in the whole line from north to south 660 miles, forming the longest direct line possessed by any one party, as far as I am aware, and linking the waters of the North and Baltic Seas with those of the Mediterranean.

* See previous Note, where it is stated that the line has been ceded to a private company.

DISTRIBUTION OF COAL IN THE BRITISH ISLES.

One of the objects of this paper being the comparison of the resources of Styria with those of the British Isles, particularly with reference to Durham and Northumberland, I conceive it will not be out of place to give an account of the distribution of the coal and coke produced in the latter counties, as a confirmation of the estimates given in No. 1 of the preceding tables; for particulars and names of pits, see my paper on the duration of the Great Northern Coal-field, Vol. II, page 287, and Vol. III, page 375, &c. The Great Northern Coal-field comprises 200 working pits, included in 136 collieries, which are in the hands of less than 90 individuals or firms, as follows:—

F. A. Vane, Marchioness of Londonderry,—Seaham, Rainton, Pittington, Penshaw, Old Durham, Lady Seaham, and Antrim
Earl of Durham,—Houghton-le-Spring, Little Town, Newbottle, Sherburn, Sherburn House, Shadforth and Lady Durham
Hetton Coal Company,—Messrs. Cochrane, N. Wood, Philipson, Burrell, Dunn, Executors of Armorer Donkin, Smart, and others,—Hetton, Elemore, and Eppleton, near Houghton-le-Spring
North Hetton Company,—Messrs. Wood, Philipson, Burrell, and others,—Kepier Grange, Moorsley and Seaton
Haswell and Shotton Company,—Messrs. Clark, Taylors, Plummer, Maude, Laws, and Bell
South Hetton Company,—Messrs. Forster, Walker, Burrell, Green, P. Forster, and J. Forster,—Murton; —Ditto and Percival Forster,—Kelloe;—and John Forster,—Trimdon Grange
Thornley Company,—Messrs. T. Wood, Gully, Chaytors, and Burrell,—Ludworth, Thornley, and Trimdon
Messrs. J. Bowes, Hutt, N. Wood, & Chas. M. Palmer,—Marley Hill, Dipton, Pontop, Greencroft, Andrews House, Norwood, Kibblesworth, Springwell, Crookbank, Killingworth, Seaton Burn, Burnopfield
Nicholas Wood, Esq.—Tees Wallsend, Black Boy, Coundon, Westerton, and Leasingthorne
Messrs. W. Blackett, N. Wood, Anderson, and Philipson,—Harton, St. Hilda, and Jarrow Collieries
Townley Stella Company,—Executors of the late J. Buddle, T. Y. Hall, C. and A. Potter, and M. W. Dunn,—Townley, Stella, and Ryton
Messrs. Bell and Partners,—Sundry Collieries,—Messrs. Bell, Backhouse, Davison, Stobart, Crawford, and Co.,—Belmont, Harraton, South Moor, Shield Row, Haugh-hall, Shincliffe, Washington, and Monkwearmouth
Joseph Pease, J. W. Pease, and Joseph Pease and Co.,—Several Collieries,—Adelaide, Bowden Close, Eldon, Hedley Hope, Jobshill, East Roddymoor, St. Helens, and Woodhouse Close
Robson and Jackson,—Hartlepool West Dock Pits, Hunwick, Byer's Green, Crowtrees, Coxhoe, West and Clarence Hetton, Heugh-hall, Newfield, and Little Chilton
Edward Richardson and Co.,—Spital Tongues, Medomsley, Eden, Derwent, Cresswell, Acorn Close Castle Pit, Langley, and Medomsley Old
James Joicey,—Stanley East, Twizell, Tanfield East, Tanfield Lea, Beamish, Tanfield Moor, and Tanfield Moor South
Messrs. Carr and Partners,—Burraton, Cowpen, Hartley, Seghill, and Felling
Messrs. J. Lamb, Potters, and Co.,—Cramlington
Messrs. J. Lamb, W. W. Burdon, Barns, Executors of Thos. Straker,—Seaton Delaval.
Messrs. Davison, Easton, W. Anderson, Stodart, Bates, and Henderson,—Bedlington.

The above companies hold, on long leases, about one-third of the Great Northern Coal-field, which may be considered equal to the better half of the field, not only because it comprises the best and probably the most profitable coal in the field, but also, because the precarious nature of the coal of some localities, which, after being worked for a short time, has been abandoned at a great sacrifice, and also the doubtful character of the portion which has not been taken up will check opposition at a distance

for at least thirty years to come, about the average unexpired term of those leases, consequently the lessees of this district, with a few of those below, may maintain their high "locus standi," and for that period represent almost exclusively the workers of the Great Northern Coal-field.

If the statement that the first named district will maintain its ground for at least half a century should be doubted, an argument in its favour may be found in the fact so well known to purchasers, that this district can produce much better coals and at a cheaper rate than the inferior districts, wherever they may be situated, particularly as the above parties represent more than two-thirds of the large capital employed, and interest on the same is not so much regarded in times of competition when the price of coal is low, as it in my opinion ought to be, thus keeping the second rate or inferior districts still lower in price; when, therefore, the former is making only a small profit, or perhaps, in many instances, no profit, the latter, if brought into the market in competition, would be sold at a considerable loss.

The remainder of the firms, possessing each only a small extent of territory, comprised in the Great Northern Coal-field, are as follows:—

Messrs. Hugh Taylor, Plummer, and Co.,—Holywell Old, Holywell New East, and Earsdon
Messrs. Hugh Taylor, C. Lamb, and Waldie,—Backworth and West Cramlington
Messrs. J. Lamb, Potter, and Jobling's Trustees,—Wallbottle
Losh and Co.,—Tyne Main and Friar's Goose
Messrs. Robert Fletcher and John Sowerby,—Burnhope Flat, near Lanchester
J. Bell and Hunter,—Framwellgate, near Durham
Wm. Hunter and Co.,—Benton, near Newcastle
Hunt and Co.,—Ouston and Urpeth, near Chester-le-street
W. C. Curteis and Co.,—Pelton, near Chester-le-street
Consett Iron Company,—Conside Pits, Crook Hall and Black Hill Pits
Geo. Elliott and Jonasshon,—Oxclose, Usworth, and Nettlesworth
Messrs. Cook and Co.,—Castle Eden Pit
Messrs. Hedley's Cregshead and Homeside
Executors of Messrs. Brandling,—Gosforth; Bell and Brandling,—Coxlodge
Mr. Tyzack,—Edmondsley
Messrs. Dalton, Johnson, and Co.,—Heaton
Messrs. Easton, Anderson, and Co.,—Hebburn and Oakwellgate, Gateshead
J. B. Pearson, Wm. Anderson, Ralph Dixon, and Kirkley,—Heworth
Ralph Dixon,—Kepier
Cookson, Cuthberts, and Liddell,—Mickley
Skinner,—Marshall Green
Birkinshaw's Trustees,—Netherton
Messrs. Longridge,—Barrington
W. W. Burdon, and W. Barkus, jun.,—Allerdean
W. W. Burdon,—Team
C. Attwood and Co.,—Black Prince, Thornley, and Towlaw
J. B. Blackett, M.P.,—Wylam
Thos. Sowerby, Phillips, and Co.,—Waldridge
Surtees and Co.—Whitworth
Mr. Kirsop,—Witton Park
John Munde Ogden,—Whitwell
Lord Howdon and Co.,—Wingate Grange
Messrs. N. G. and F. D. Lambert, Executors of Robert Nicholson and Thomas Garton,—Walker
N. G. and F. D. Lambert, Executors of Robert Nicholson and Thomas Gorton, Geo. Jobling, Geo. Cruddace, and R. B. Byass,—Rebside
Joseph and John Harrison, and Carle Lange,—Radcliffe
Messrs. D. Burn, R. Hawthorn, W. Anderson, R. Rayne, and Geo. Clark,—Stanley West
Straker and Love,—Bitchburn, Brancepeth, and Willington
Messrs. Bolckow and Vaughan,—Auckland West, Etherley New, Woodfield, and Whitlee
Messrs. Henry Stobart and Backhouse,—Etherley Old and Bitchburn North
Marquis of Bute's Executors,—Chopwell
Messrs. Harrison, Carle Lange, Geo. Lee, M. Henderson, Wm. Dickinson, &c.,—Ashington
Carr Brothers,—Bell's Close
Joseph Cowen,—Blaydon Burn
G. H. Ramsay,—Blaydon Main
Armstrong,—Evenwood
W. H. Bell,—Sacriston
Muschamp,—New Bitchburn
Pratman's Trustees—Butterknowle
Messrs. Matthew Bell and M. Johnson,—Willington
Messrs. James Losh, John Johnson, William Reay, and Anderson,—Tyne Main
Messrs. Gooch and Co.,—Lintz, near Gibside

The distribution of the produce of the above districts was, in 1854, as follows:—

		Quantity.	Shipping.	By Ironworks.	By Sundries. By rail, cart, and canal.
			Tons.	Tons.	Tons.
No. 1, A.	Durham and Northumberland	16,221,101	.....	.....	.....
	Shipped from East Coast	.....	.....	.....	.....
	Do. from West Coast by railway, viz., 92,014 (each including the coal made into coke).	.....	8,688,551	.....	.....
	By Midland and Great Northern Railway	.....	.....	.....	163,914
	Coals for coke between Newcastle and Leeds	.....	.....	.....	22,200
	Coke south by railway	.....	.....	.....	1,046,536
	Local Trade between Newcastle & Carlisle	.....	.....	.....	300,000
	Do. landsale and landsale pits, at a distance from Northern Coal Field, also consumed by working coal	.....	.....	.....	1,699,800
	Iron trade	.....	.....	4,300,000	.....
	Total	16,221,001	8,688,551	4,300,000	3,232,450

DISTRIBUTION OF THE OTHER THREE DISTRICTS.

		Quantity.	Shipping.	By Ironworks.	By Sundries. By rail, cart, and canal.
			Tons.	Tons.	Tons.
No. 2, B.	Cumberland	887,000	.....	.....	.....
	Yorkshire	7,260,500	.....	.....	.....
	Derbyshire	2,466,696	.....	.....	.....
	Nottinghamshire	813,474	.....	.....	11,228,977
	Warwickshire	255,000	.....	.....	
	Leicestershire	.....	.....	.....	.....
	Half Worcestershire, & half Staffordshire	3,500,000	.....	3,862,780	.....
	Total	15,811,670	719,913	3,862,780	11,228,977
No. 3, C.	½ Worcestershire and ½ Staffordshire	3,750,000	.....	.....	.....
	Lancashire	9,080,602	.....	.....	.....
	Cheshire	726,500	.....	3,734,693	11,867,673
	Shropshire	1,080,000	.....	.....	.....
	Gloucestershire, Somerset and Devon	1,492,366	.....	.....	.....
	Total	16,189,366	587,000	3,734,693	11,867,673
No. 4, D.	Flintshire, Denbighshir. and Anglesea	1,143,002	.....	.....	.....
	Monmouthshire, Glamorganshire, and Pembrokeshire	8,500,000	2,995,015	5,250,000	 2,765,703
	SCOTLAND	7,448,000	829,032	5,400,000	.....
	IRELAND	148,750	.....	.....	.....
	Total	17,239,750	3,824,047	10,650,000	2,765,703

The foregoing statistics,—taken, as near as possible, in the same way—are in confirmation of the former tabular forms for quantities noted for different counties, under separate heads, (Nos. 1, 2, 3, 4, Pages 68, 69, and 70). Having thus shown the distribution for Durham and Northumberland, I have divided the total quantity, 65½ millions of tons, under three heads, as in former table—shipping, iron trade, and sundries.

AGGREGATE DISTRIBUTION OF THE UNITED KINGDOM.

No.	Yearly Production in Tons.	Shipped.	For Iron Working.	Sundries.*
1. Durham and Northumberland....	16,221,001	8,688,551	4,300,000	3,232,450
2. Seven Counties, as above	15,811,670	719,913	3,862,780	11,228,977
3. Eight Counties, as above	16,189,366	587,000	3,734,693	11,867,673
4. North and South Wales, Scotland, and Ireland	17,239,750	3,824,047	10,650,000	2,765,703
Total.....	65,461,787	13,819,511	22,547,473	29,094,803

ABSTRACT OF THE ABOVE.

Total Tons Shipped	13,819,511
Ditto For Iron Working	22,547,473
Sundries	29,094,803
Total Yearly Tons	65,461,787

The largest production of iron from one English furnace ever known was 270 tons in one week, at the New British Iron Company's Works, Ruabon, under the superintendance of Mr. Thorburn, who has, with the same furnaces, produced on an average 250 tons weekly, for the last four months. The above is the largest weekly production by one furnace in the world, and more than double the quantity I have averaged the furnaces at in the aforesaid statement, which would require for the production of iron the full quantity of coal I have put down yearly.

*The difficulty of procuring accurate returns of the distribution by canal and railway has compelled me to place those items under one head, to make up the total in each district. The returns for shipping and iron works are more easily obtainable, and the remainder I have placed to the account of sundries in each of the four districts. It is probable that part of the quantity placed to the account of sundries may have been shipped, thus lessening the amount of sundries and increasing that of shipping.

APPENDIX A.

ANALYSATION OF ORES, &c.

The subjoined analyses of samples of coal which I obtained from the Buchberg and other mines at the time of my visit, have been made by our eminent local chemists, Messrs. Richardson and Browell, of this town :—

Samples.	Concessions.	Description of Seam.	Thickness in Feet.	Coke		Gaseous Matter.	
				Carbon.	Ashes.		
1	Antoni-di-Padua	Middle	..	52·6	3·9	43·5	100·0
2	Theresia	Do.	14	45·0	5·5	49·5	100·0
3	Joseph	Do.	14	44·0	5·0	51·0	100·0
4	Petschounig	Upper	11	42·5	7·5	50·0	100·0
5	Edward	Middle	14	37·0	3·5	59·5	100·0
6	Lutzia	Upper	..	45·5	8·5	46·0	100·0

None of these coals, say Messrs. Richardson and Browell, cake, except one, which, however, only possesses this property in a slight degree. They burn with little or no flame, and evolve a peaty smell when submitted to distillation. The ash is of a grey colour, but tinged in places with oxide of iron. It consists of silica, alumina, oxide of iron (in small quantities), gypsum, &c. The ash does not slag. The proportion of fixed carbon approaches that left by lignite and some varieties of cannel coal.

A sample of bog iron ore, which was taken from a rich vein in the hill of Essenberg, contains only 1·40 per cent. of insoluble matter, and 88·8 per cent. of peroxide of iron. Besides this one, the following were examined, viz. :—2, Sample from a hill at Essenberg, Concession No. VII., Galizien, Styria. 3, Bog Iron Ore, specimen of the Mass-hill of Essenberg, Styria. 5, Oxide of Iron (compact) cropping out in a rivulet at Essenberg, Concession No. VII. 6, Hematite, Oxide of Iron, from a rich vein of Ore occurring in Muschelkalk, at Essenberg, in Concession No. VII. They differ little in their chemical composition from the first mentioned; being all rich in iron, and containing a small quantity of insoluble matter (sand and clay). No. 3 contains more insoluble matter and less iron than the others.

Besides the coal samples enumerated above, I obtained a variety of samples of various other kinds of ores, which I have presented to the Museum connected with the Institute. They include a specimen of grey

rock* from the *upper* stratum of the Lutzia Concession; a sample of Blende or zinc ore occurring in calespar and limestone on the banks of the river Poik; also, several fine specimens of oxide of iron and copper, sulphate of copper, iron pyrites, &c., &c., all obtained from different concessions in that district. The Museum would be very much enriched if, besides these, the vast quantity of samples of ores, amounting to upwards of 100lbs. weight, which I obtained when on a visit to Rhenish Prussia—deputed to inspect the coal concessions of Ruhroort, and the iron mines of Eitorf and Neuwied, in that country, by the President of the Institute, Nicholas Wood, Esq.—and which I believe are now in the possession of that gentleman, or Mr. P. S. Reid, who was in Prussia with me, were deposited therein. A great many of them, like the above, have been analysed by Dr. Richardson and Mr. Browell.

* The Grey Rock here spoken of is of a very different nature to that which I observed in Prussia. In the latter country it is of a more angular and flinty nature, and the mountains which contain it are of a more strikingly jagged character. In the Styrian districts it is of a rather sandy consistence, as the sample in the Museum will show. Near Prague it is very regular. The ancients applied the term "Greywacke," or grey rock, to a whole series of strata, from the lowest sediment to the millstone grit inclusive. Modern geologists, however, have separated the series into separate natural history groups; and that portion of it which is now called "Greywacke" is placed at the bottom of the secondary series, immediately below the old red sandstone formation. It is found very extensively in Germany, Prussia, and neighbouring continental countries, and it is also found along the western coast of England and in the south of Scotland, more particularly in the Lammermoor Hills, and in the Pentland Hills, near Edinburgh. It is a stratified rock, composed of quartz, Lydian stone, felspar, and clayslate, imbedded in a base of clayey matter. The transition rocks of Werner are almost wholly composed of this "Greywacke."

Note on the Iron Trade.

Many a mining bubble having been blown within these last 50 years, it may be a matter of information to show the fluctuations of the iron trade at various periods since the commencement of the present century, 1805 to 1855, as affording fair comparisons. It is not for me to enquire into the causes of these fluctuations, I leave the facts to speak for themselves.

PRICES, EVERY FIVE YEARS, OF PIG AND BAR IRON.

	Best Bars. £ s. d.	Pig Iron. £ s. d.
1805	22 10 0	8 5 0
1810	18 10 0	8 0 0
1815	17 0 0	8 5 0
1820	14 10 0	8 0 0
1825	15 10 0	7 10 0
1830	8 10 0	3 0 0
1835	8 15 0	3 10 0
1840	11 15 0	4 10 0
1845	11 0 0	3 15 0
1850	7 5 0	2 6 0
1855	10 10 0	3 10 0

Occasionally fluctuations have taken place for short periods, and pig metal and bar iron have, for a short time, been at lower prices than quoted above.

APPENDIX B.

THE GROTTO OF ADELSBERG.

The celebrated subterranean cavern which bears this name is situated about 2½ miles east of Trieste, and on the post road from that city to Plansna and Laibach. Its length as far as it has yet been explored, is upwards of two miles. It is probable, however, that the end of this vast cavern has never yet been attained, and that its extent is far beyond what modern explorators have supposed. From end to end it abounds in natural beauties, and is at once the most magnificent and the most extensive in Europe. The caves of our own isle sink into utter insignificance when placed in comparison; those of Derbyshire—the most famous and the largest of our subterranean openings being in size, appearance, and all those general characteristics which attract the lover and student of nature, but as the mere side chambers of the giant Austrian cavern. It is, unfortunately, but little frequented by English travellers, who, in omitting it lose one of the most magnificent natural scenes of the kind in the world.

The following description of this celebrated subterranean grotto I have condensed from materials supplied me, which have been translated from German into English by my neighbour Dr. Charlton.

The grotto comprises two large divisions, viz., "The Old Grotto," extending from A to C on the accompanying plate, and the new, or famous "Crown Prince Ferdinand's Grotto," extending from A to B. Up to the year 1818 the old grotto was the only explored portion of this vast cavern. It was there that Valvasoi saw the wonderful demons and genii of the mines, and there that he experienced those sensations of horror and awe, which he has so vividly described in his work "Die Ehre des Herzogthums Krain." It was there, too, that some unknown traveller having lost his light, and consequently all knowledge of his way, laid himself down to meet the horrible fate which awaited him, and to this day his petrified skeleton remains, "a warning and a tale." Upon the wall immediately above it are inscribed the names of former visitors to the grotto some of them are not less than four hundred years old, but beyond their antiquity they possess little or no noticeable interest. In a short time these and all the old grotto contains will be things of remembrance; the entrance to that portion of the cavern having become nearly, if not wholly, inaccessible. The constant formation of the stalactites, tends gradually to narrow the point of ingress, and to such an extent had this been accomplished when the writer visited the place, that a tolerably stout man might in vain have attempted to enter.

The other portion of this vast subterranean opening is that to which we intend particularly to allude, and may be said to commence at the Monument of Kaiser Franz, (*No.* 3 *on Plate* 5; *see also Plate* 5, *A*). This structure, situated at one extremity of a spacious hall, ninety feet high, and a hundred and forty four feet wide, is a huge unwieldy pile of masonry, erected to commemorate the visit of the Emperor Francis the First, and, till the year above-mentioned, was supposed to form the extreme southern boundary of the grotto. In that year, however, the modern division of the cavern was discovered by a

somewhat singular accident. Inspector Von Löwengreif, anxious to afford their Majesties, the Emperor and Empress of Austria, the spectacle of a complete illumination of the vast hall in which the monument is placed, had constructed, with immense difficulty and danger, a staircase down the perpendicular face of the precipice to the edge of the river Poik, which enters the cavern a short distance below the outer doorway. Having thrown a bridge across the water, and thereby gained the opposite side, he planted his lanterns in a position to produce the desired effect. This done, he naturally stood for a few minutes contemplating the sublime scene before him. The glare of the lanterns rendered nearly every nook and cranny of the lofty apartment visible, and Löwengreif, casting his eyes upwards, was surprised to see, at a height of about fifty feet, a recess of considerable dimensions, the entrance apparently to another spacious chamber. The nature of this large opening he determined to ascertain at all hazards, but for upwards of a year, the difficulty of procuring materials to accomplish the ascent, deterred him from prosecuting the enterprise. At length, by dint of great skill and perseverance, he completed his object, and thus paved the way for subsequent, and, as the annexed plates show, successful explorations into the heart of this magnificent cavern.

The modern visitor, after crossing an elegant wooden bridge, beneath which the impetuous waters of the Poik rush and roar, ascends a steep flight of stairs—comprising no less than eighty-two steps—to the opening discovered by Von Löwengreif. Having entered a rough and massive portal, he finds himself in a large arched vault, and surrounded on all sides by stalactites of every conceivable form and size, many of them being of dazzling brilliance and surpassing beauty. The sublimity of the scene is materially enhanced by a deathly silence, which pervades the whole apartment. The murmuring waters are hushed, the dropping of the stalactites is no longer audible, and, save the echo of the voice or a footstep, an unbroken stillness reigns. In the main avenue, which diverges considerably to the right of this chamber, are some of the finest stalactites in the Grotto. In one place the stalagmite from the surface and the stalactite from the roof have united, forming an unique and curiously-formed pilaster in the very centre of the passage. At another spot large lobe-like masses of stalactite are suspended from the arched vaulting by a slender stalk, so that, viewed by the flickering and uncertain glare of the torches, they bear so exact a resemblance to the hams and flitches in a bacon-factor's shop, that the visitor can readily agree to the name of the "Fleischbauk," Butcher's Bench (4), which has been bestowed upon them. A little further on is a very pretty, though somewhat small, recess, named the "English Garden" (5). The floor is entirely covered with beautiful white stalagmites, from three inches to three feet in height, and, from their uniform cylindrical shape, they really resemble the formally-cut box and yew trees of an old-fashioned English lawn or shrubbery.

Re-entering the main passage, without tarrying to notice the "Dolphin and Lion" (6) and "the Throne" (7), which, though striking, are by no means extraordinary, a pair of very singular stalagmites present themselves (8). They bear the form of two hearts placed side by side, and so minute is the resemblance that the hand of the experienced sculptor could scarcely have produced more accurate models. A brisk walk brings the visitor to another subterranean wonder, the Iron Tree (9), or "Stock am Eisen," so called in allusion to the famous tree in Vienna, into which every apprentice had to drive a nail. Various objects of interest here present themselves in succession, but none call for particular mention until we arrive at the "Tanzsaal, or Tournament Place" (13), so faithfully depictured in the annexed lithograph. The Tanzsaal is a huge vaulted cavern, the roof of which is exceedingly lofty, and traversed by massive ribs of rock not unlike the vaulting of some old Norman cathedral. Its length is a hundred and fifty feet, and it gains much in grandeur on ordinary occasions by the impracticability of producing the requisite amount of light to render the whole of its gigantic proportions visible. Once a-year, however, it is brilliantly lighted up for a subterranean festival, when it becomes the resort of the peasantry for many miles around, and is the scene of boundless mirth and pleasure. The engraving represents the hall in a state of partial illumination, and, though the pencil of the artist can never adequately pourtray the all-pervading grandeur of these stupendous caverns, we trust it will give the reader something of an idea, however faint and feeble, of the majestic and impressive scenery with which this grotto abounds.

After leaving the Tanzsaal, the stalactites become less numerous and frequent, and the visitor is conducted for some distance along a gallery of naked rock, the roof of which, in various places, is fifty or sixty feet above the level of the floor. From time to time, however, stalactites of varied and striking form appear, and when this occurs

the objects they are supposed to represent are seen to greater advantage from the circumstance that all around and above them is dull, unvarying rock. One group, so isolated, is called the "Tabernacle" (16) from its resemblance to the Gothic shrines of the Blessed Sacrament, such as one sees in the Church of St. Lawrence at Nuremburg. Another has received the unromantic name of "Die aufgehangene Wasche," or the "linen hung up to dry;" and a third is called "the Charcoal Furnace." Not far from this latter is an enormous stalactite, pendant from the rocky roof about eighteen feet, and, at its extremity, twelve or fourteen feet in breadth. In the very centre of this mass is an apparently dissimilar substance, of a deep brownish red colour, and in shape a parallelogram. It appears to be let into the stalactite, the latter forming a kind of framework around it, hence it has received the name of "the Picture" (18); and, as its colour is a deep red, whilst the stalactitic frame is a remarkably brilliant white, it not inappropriately bears that designation. Immediately beneath it a huge block of stalagmite ascends, and nearly, if not quite, joins the mass above, giving the whole the appearance of a massive obelisk raised in honour of some redoubtable demon or spirit hero, whose triumphs were to have been imperishably inscribed upon the central tablet, or configured around the sides of the column itself.

Passing by "the Mummies" (12), and "the Grave" (20), as objects too melancholy for contemplation in this cavern of so many beauties, we reach "the Ruffles" (21), as shown on the accompanying plate. This beautiful formation is a curtain of alabaster, so thin and fine that the flame of the torch is distinctly visible through its transparency. This will be seen more plainly by a reference to the plate, where one of the guides is shown in the act of placing his torch behind the curtain in the position described. The country people call it "the Shirt Frill," and its vandyked form and wavy outline present an appearance somewhat similar to that old-fashioned article of dress. Immediately opposite will be observed a column of stalagmite broken across about four feet from the ground. Its upper part leans against the wall of the Grotto, and a smaller pillar has begun to form directly above the fracture from the same dropping which, in all probability, deposited the original column. A short distance further are two tall pillars (*see background of plate,*) named the "Greater and Lesser Cypresses" (22), the latter of which is twenty-one feet in height. The next object of interest, and one which perhaps surpasses in elegance the Shirt Frill, is "the Curtain" (23). The magnificent stalactitic drapery which bears this name is pendant from the limestone rock, at a height of about nine feet. Its breadth is not more than a yard, and its thickness from three to four inches. Nothing can exceed the marvellous delicacy and gracefulness of its folds, while to render the illusion more complete, a stream of water strongly impregnated with oxide of iron has tinged its edge with a most exquisite brown and red border four inches wide. From this point to the Calvarien Berg or "Mount Calvary" (28), the scenery is of the most monotonous character. The principal object of interest in the route is a little pool, not that of itself it is anything remarkable, but because it contains some living specimens of the Proteus Anguinus, a strange, flesh-coloured, lizard-like, little animal, furnished with gills and feet, destitute of eyes but having small points and possessing an excessive development of head. The animal is supposed to be

confined to this and the Magdalenen Grotto, a short distance from Adelsberg; hence the curiosity it excites (*see Plate* 10).

Sir Humphrey Davy says:—"At first view, you might suppose this animal to be a lizard, but it has the motions of a fish. Its head, and the lower part of its body and its tail, bear a strong resemblance to those of the eel; but it has no fins, and its curious branchial organs are not like the gills of fishes: they form a singular vascular structure, almost like a crest, round the throat, which may be removed without occasioning the death of the animal, who is likewise furnished with lungs. With this double apparatus for supplying air to the blood, it can live either below or above the surface of the water. Its fore feet resemble hands, but they have only three claws or fingers, and

are too feeble to be of use in grasping or supporting the weight of the animal; the hinder feet have only two claws or toes, and in the larger specimens are found so imperfect as to be almost obliterated. It has small points in place of eyes, as if to preserve the analogy of nature. It is of a fleshy whiteness and transparency in its natural state, but when exposed to light its skin gradually becomes darker, and at last gains an olive tint. Its nasal organs appear large; and it is abundantly furnished with teeth, from which it may be concluded that it is an animal of prey; yet in its confined state it has never been known to eat, and it has been kept alive for many years by occasionally changing the water in which it was placed. It has been found of various sizes, from that of the thickness of a quill to that of the thumb, but its form of organs has been always the same. It is surely a perfect animal of a peculiar species. And it adds one instance more to the number already known of the wonderful manner in which life is produced and perpetuated in every part of our globe, even in places which seem the least suited to organized existences.—And the same infinite power and wisdom which has fitted the camel and the ostrich for the deserts of Africa, the swallow that secretes its own nest for the caves of Java, the whale for the Polar seas, and the morse and white bear for the Arctic ice, has given the Proteus to the deep, and dark subterraneous lakes of Illyria,—an animal to whom the presence of light is not essential, and who can live indifferently in air and in water, on the surface of the rock, or in the depths of the mud."

In another portion of this dreary avenue, and a little further ahead, the calcareous matter seems as if it had been suddenly arrested whilst rolling in a liquid state over the rock, and its appearance is not unlike that of a waterfall. As a relief to the tedious monotony of the road, this is a rather striking object; in any other part of the Grotto it would receive but little attention. After leaving it, jagged abutments of limestone and uncouth projections of the naked rock constitute the whole of the scenery until we reach the gate of the Calvarienberg. Once there, the view more than compensates for the dreary length of the passage. The roof rises to an immense height, while the surface is studded with innumerable stalagmites of the most grotesque shapes and fantastic hues. The prevailing colours are white and red, and it is somewhat singular that the white stalagmites invariably form the sponge-shaped and tubular masses, while the red shoot up into tall and slender pillars. Many of the latter are deeply and uniformly grooved, while others are like buttresses with regular offsets. Indeed, nearly every style of pillar and column is represented, varying in shape according to the position from which the stalagmite is viewed. (*See Plate* 10.)

And now, having left "The Difficult Pass" (25) behind him, the visitor arrives at the foot of Mount Calvary, a stalagmitic hill of large proportions. It retains the singular name of Calvary in compliment to the pious feelings of the early explorators, who invested the whole apartment with sacred interest, from the fancied resemblance it bore to the memorable scene of the crucifixion. A kind of central pillar is called "The Redeemer's Cross;" another pillar is called after St. John; a third is named "St. Stephen's" (27); while in the vicinity are various objects which, suggestive of different incidents in the closing scene of Christ's life, have received appropriate appellations. Here the visitor may tarry long, and feast his eyes with fresh marvels; the resources of the Berg being comparatively speaking unlimited. If he have a taste for exploration he may travel the passages indicated on the plan by dotted lines, and which abound in the locality. Or, on the other hand returning to the main avenue, he may proceed for a quarter of a mile along the bare rock to the supposed extremity of the cavern, a small lake (31), over which an adventurous Englishman not long since swam; or, like hundreds of others, he may hasten back to the blessed light of day and the pure river breezes which await him above, edified by what he has seen, and influenced by any feelings but those of regret at having spent the greater part of the day at the far-famed Grotto of Adelsberg.

REFERENCE TO PLATES IN BOOK.

General Map of the Austrian Empire with the Railways & Intended Railways. the Boundaries of Provinces, & proposed rectified Russian Boundary.

PLAN *1. Map from Vienna to Trieste with part of Austria.*

" 2. Map near Cilli – Styria shewing different Ore Districts

PLATE *9. Shaded portion of Plan shewing the Durham and Northumberland Coal Field with lines for intended Section lines marked from 1 to 5 and Iron Ore districts from A to V in Red.*

3 Position of Coal Seams near Cilli. 7 miles from Cilli, 5 direct). 5 direct to Buchberg.

3ª General position of Coal Seams and Strata in Prussia, France, & Belgium with sketch of a Welsh Coal Seam, shewing the top become the bottom of the seam.

4 View of Country near Cilli shewing Lehens & Muthungs

8 Mountain view of Coal Mines at Buchberg

5 View of Country above the Grotto, with Grotto underneath

5ª Monument to his Imperial Majesty Francis 1st above do.

6 Nos 21 & 22 in Reference. The Ruffles etc.

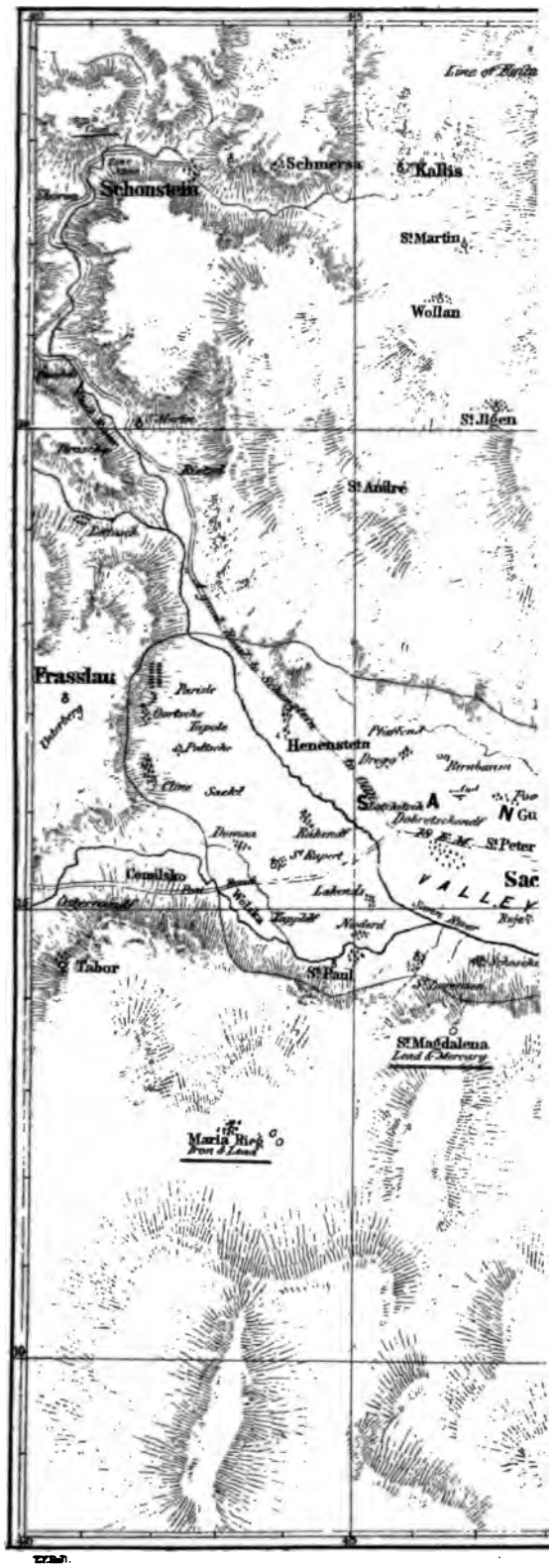
7 The Tournament Place.

10 View of mount Calvary 28 in Reference where Lizard-like fish are found.

Plates 5. 5ª, 6. 7 & 10 are all in Appendix B.

SECTION OF COAL SEAMS NEAR CILLI (STYRIA)

MAP SHEWING THE VALLEY O



SECTION OF COAL SEAMS NEAR CILLI (STYRIA)

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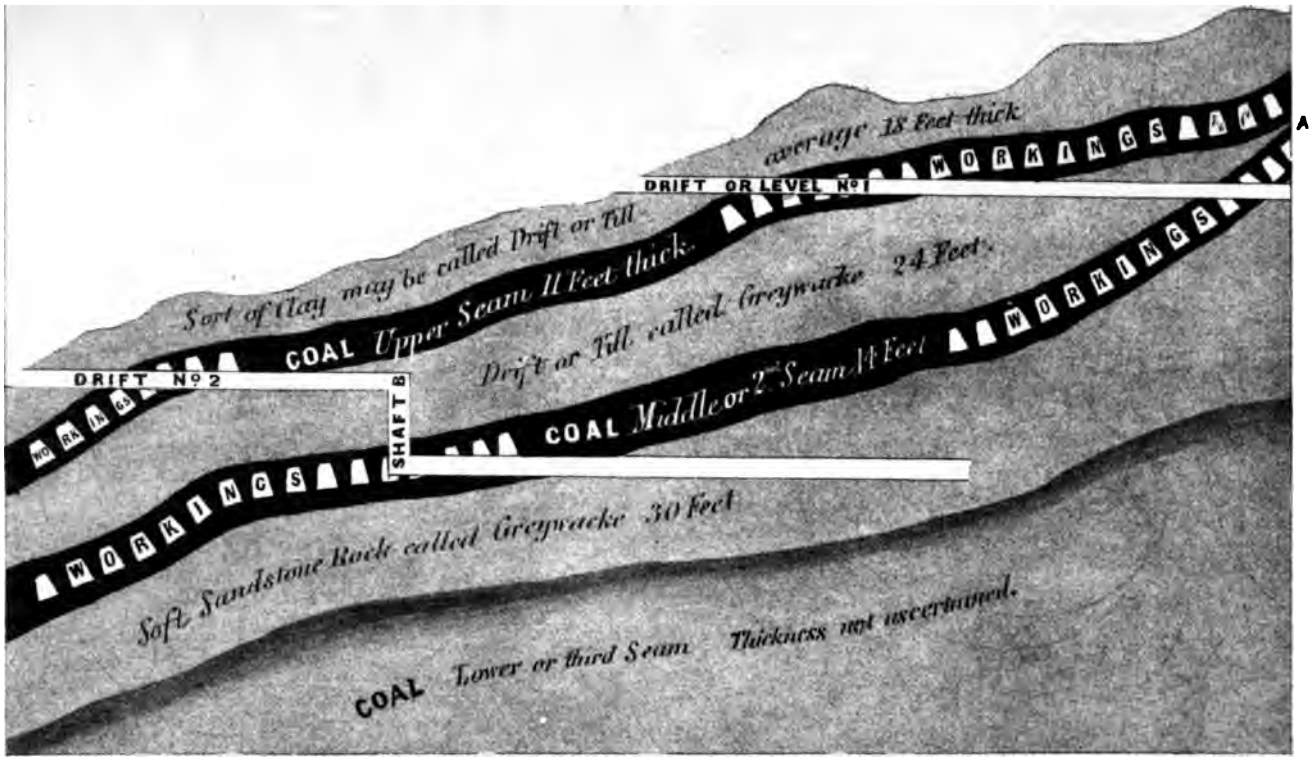

SECTION OF COAL SEAMS NEAR CILLI (STYRIA)

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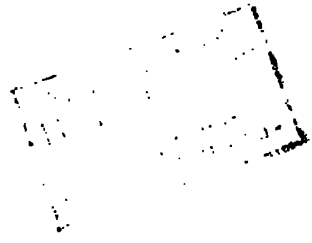
VIEW OF STYRIAN COUNTRY SHEWING SITUATION OF LEHENS AND MUTHUNG CONCESSIONS.

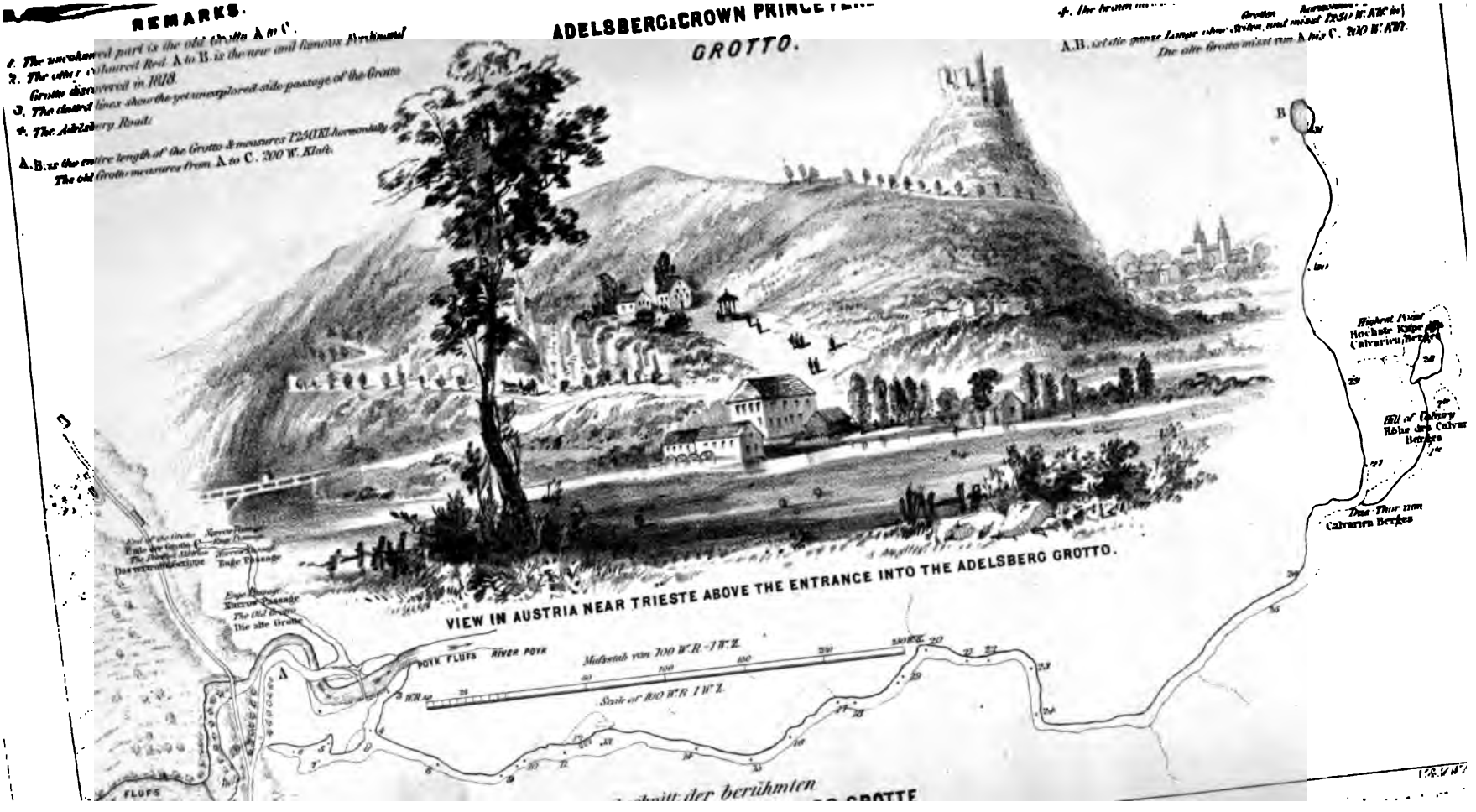


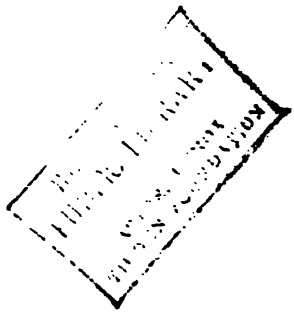
REFERENCE TO SUBTERRANEOUS GROTTO

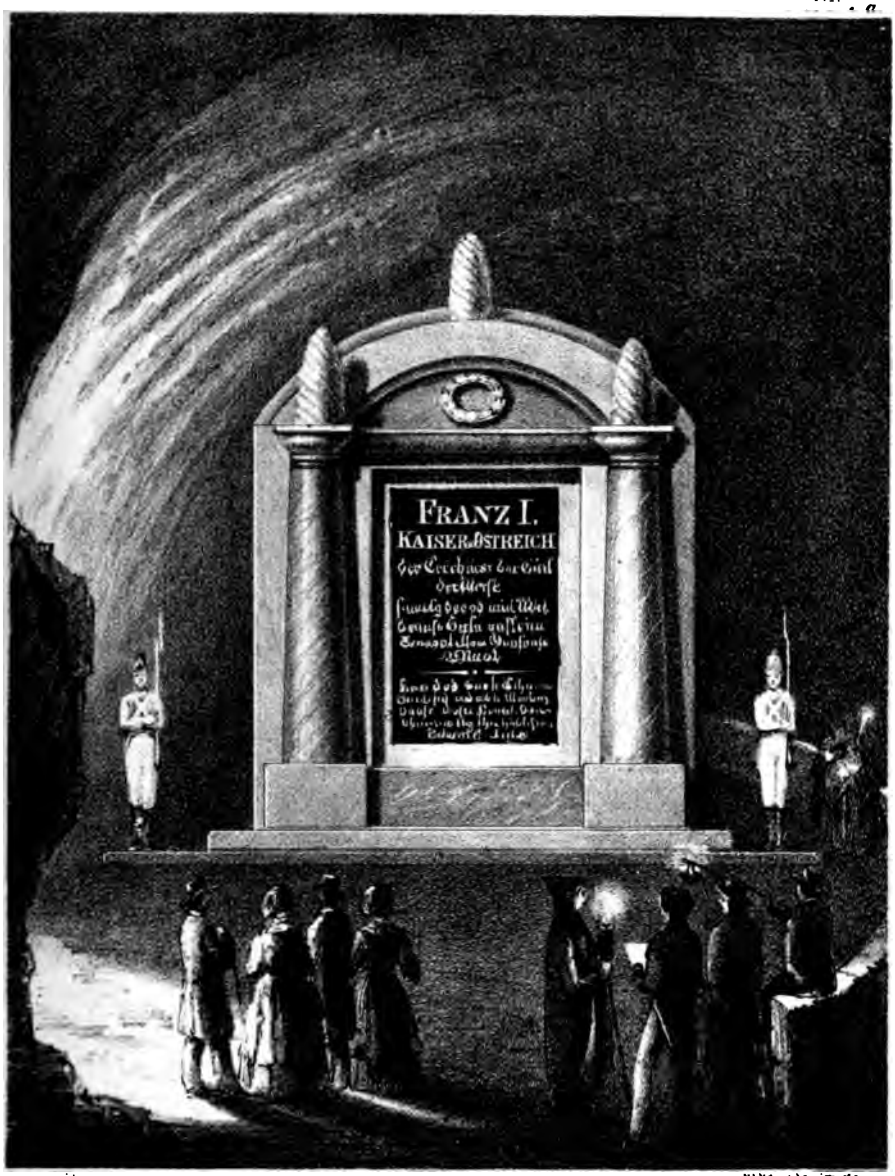
Plate No. 5.

Erklarung.	Explanation.	
1. Der grosse Dom.	1. The Great Cathedral.	PLATE 5 with Grotto underneath
2. Die Naturud Kunstbrucke.	2. The Natural bridge & Artificial Do.	
3. Das Monument.	3. The Monument.	PLATE 5a
4. Die Fleischbank.	4. The Butchers Block.	
5. Der Englische Garten	5. The English Garden.	
6. Delphin & Lowe.	6. Dolphin & Lion.	
7. Der Thron.	7. The Throne.	
8. Vereinigung zweyer Herzen.	8. Union of two Hearts	
9. Stock am Eisen.	9. The Iron Tree *	
10. Die grosse Kanzel.	10. The great Pulpit.	
11. Petri Stuhl	11. St Peters Chair	
12. Das Stockhaus.	12. The block house	
13. Der Turnier Platz.	13. The Tournament Place #	PLATE 6.
14. Der Tisch.	14. The Table.	
15. Die Glocke.	15. The Bell.	
16. Der Tabernakel.	16. The Tabernacle.	
17. Der Kohlofen.	17. The Charcoal Furnace.	
18. Das Bild.	18. The Picture.	
19. Die Mumien	19. The Mummies	
20. Das Grab	20. The Grave.	
21. Die Schapodeln (Jabot).	21. The Ruffles	PLATE 7.
22. Die Cypresse.	22. The Cypress	
23. Die Kanonen-Saule	23. The Cannon pillar.	
24. Der Vorhang	24. The Curtain.	
25. Der Beschwerliche Durchgang	25. The Difficult Pass	
26. Das rothe Meer	26. The Red Sea	
27. St Stephan.	27. St Stephens	
28. Der Kalvarien Berg	28. Mount Calvary. Part of Grotto where Lizard-like Fish are found — See Appendix B	PLATE 10
29. Der Kapuziner	29. The Capuchin Monk	
30. Der Tropfbrunnen	30. The Dropping Spring	
31. Der See als bis nunmehr schrillene Granze	31. The Lake - the furthest extreme yet reached	
† Die stelle welche I. M. Maria Louisa am 4 Juny 1830 erstiegen haben 1100 W. Klf. vom Eingange.	† The point to which the Empress Maria Louisa reached in 1830 — 1100 Viennese fathoms from the entrance.	

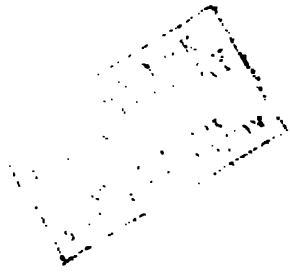
* The words "Stock am Eisen" refer to the famous Tree in Vienna into which every apprentice had to drive a nail.

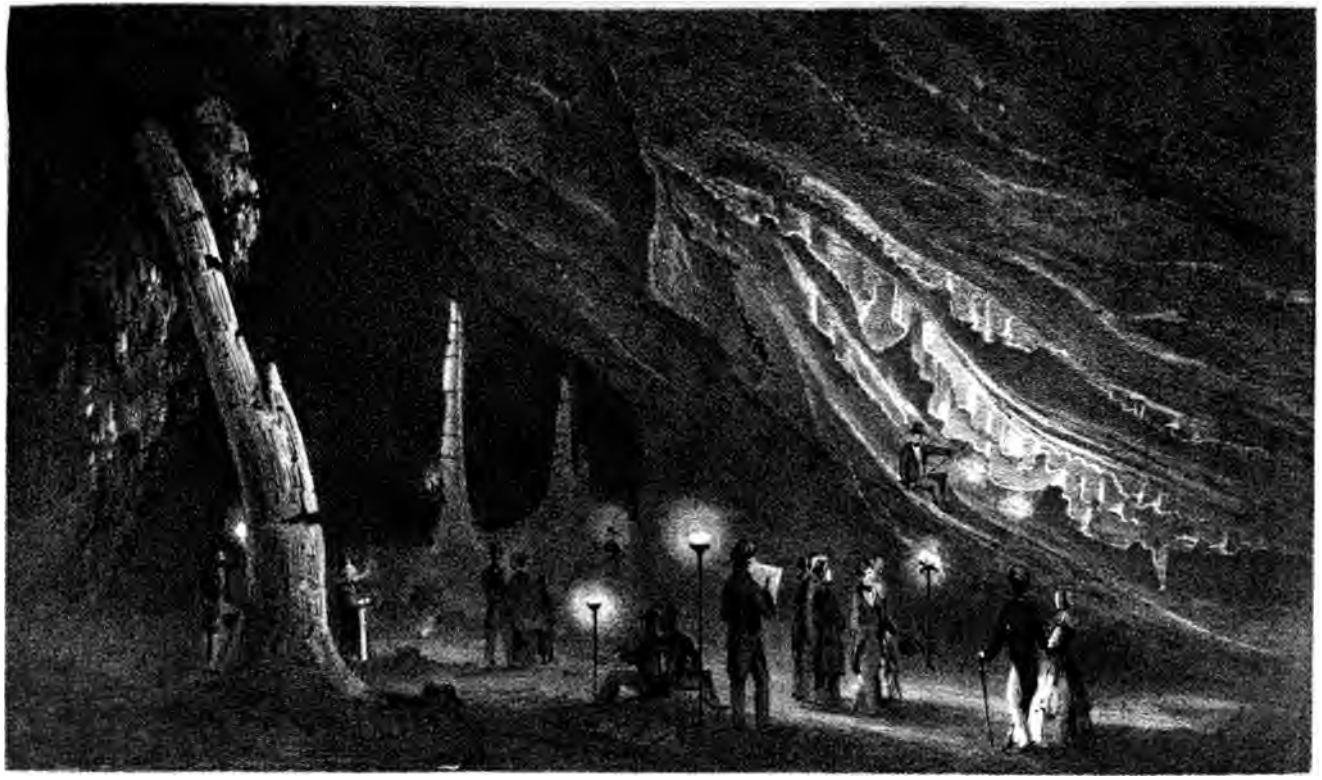

REMARKS.
1. The uncoloured part is the old Grotto A to C.
2. The other coloured Red A to B. is the new and famous Ferdinand Grotto discovered in 1818.
3. The dotted lines show the yet unexplored side passage of the Grotto
4. The Adelsberg Road.
A.B. is the entire length of the Grotto & measures 1250 Kl. horizontally
The old Grotto measures from A to C. 200 W. Klaft.
ADELSBERG & CROWN PRINCE
GROTTO.
VIEW IN AUSTRIA NEAR TRIESTE ABOVE THE ENTRANCE INTO THE ADELSBERG GROTTO.
Highest Point
Hochste Kupe des Calvarien Berges
Hill of Calvary
Höhe des Calvar Berges
Das Thor zum Calvarien Berges
Enge Passage
Narrow Passage
The Old Grotto
Die alte Grotte
POYK FLUFS
RIVER POYK
Maßstab von 100 W.R. - 1 W.Z.
Scale of 100 W.R. 1 W.Z.
FLUFS
der berühmten





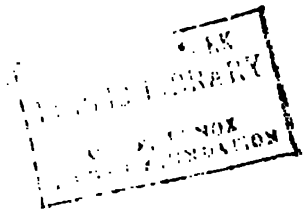
MONUMENT TO HIS IMPERIAL MAJESTY FRANCIS THE FIRST RECORDING HIS IMPERIAL MAJESTY'S VISIT TO THE CAVERN 16TH MAY 1816

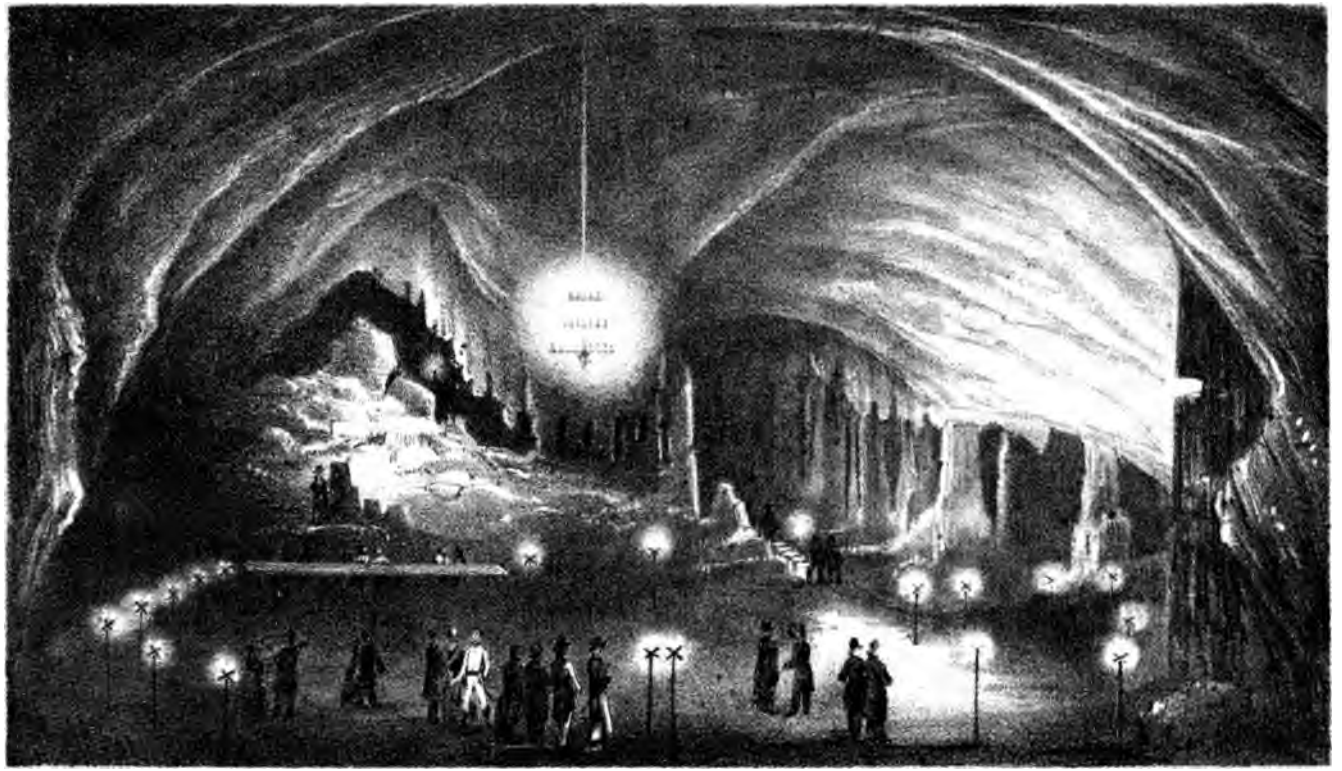




ANSICHT DER GEGEND ZU DEN SCHAPODELN (JABOTS) GENANNT.

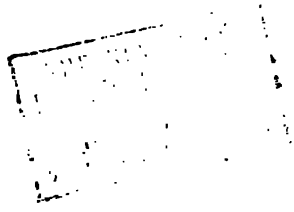
VIEW OF THE CAVE OF ADELSBERG AT THE POINT CALLED FRILLS (JABOTS)

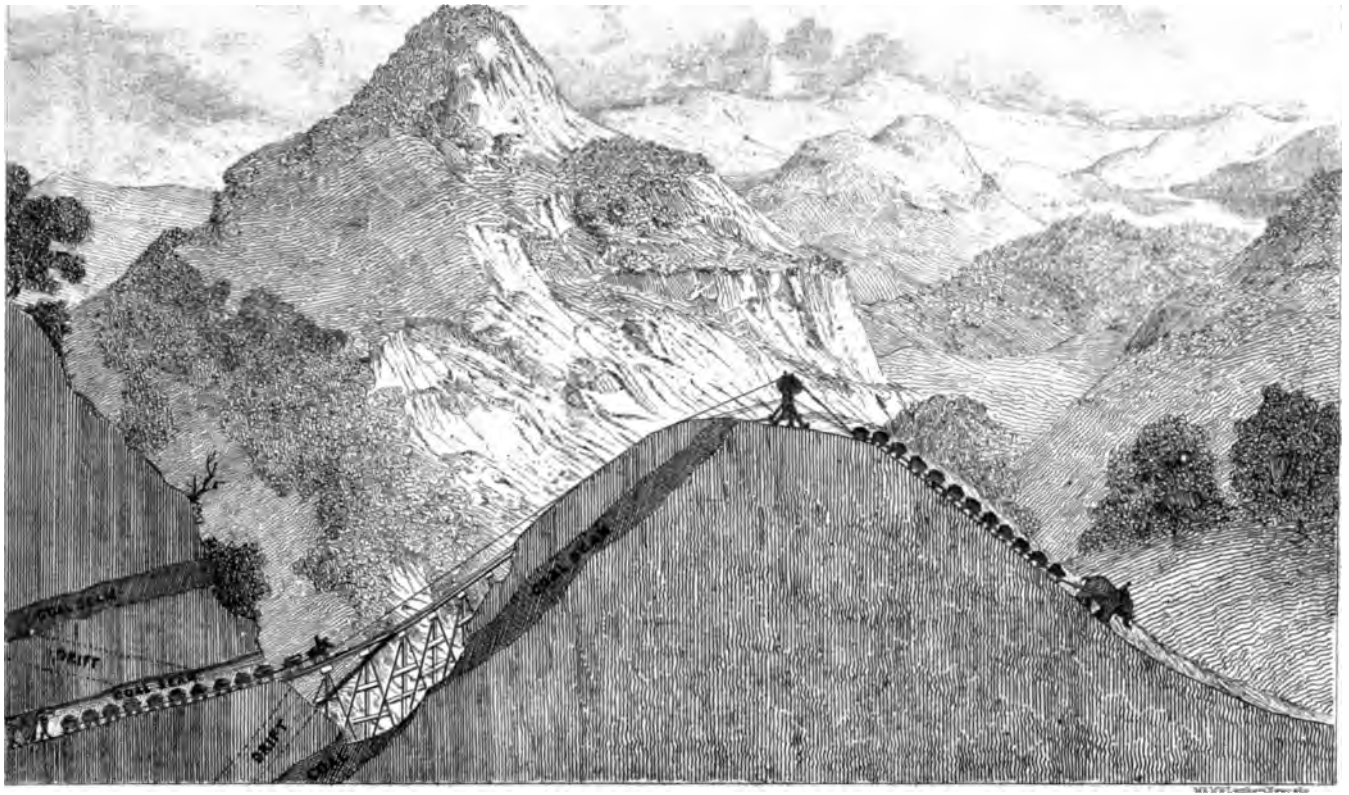




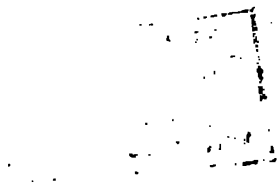
DER TOURNIERSAAL.

VIEW OF THE TOURNAMENT HALL



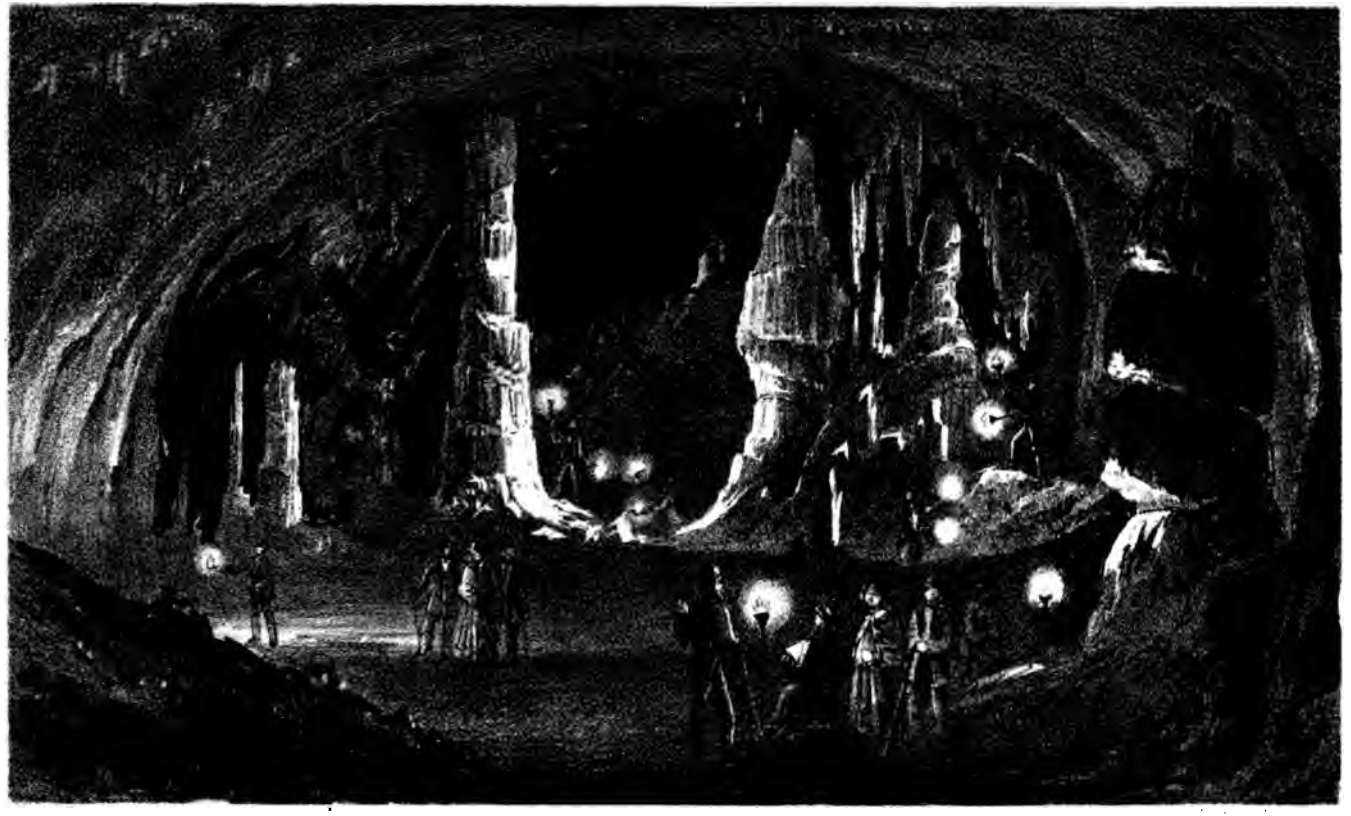


MOUNTAIN VIEW OF COAL MINES AT BUCHBERG.



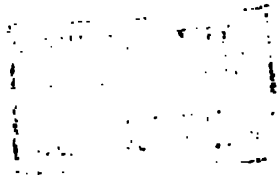
N° 28 in Reference to Grotto

PLATE 10



ANSICHT DES THORES ZUM SOGENANNTEN CALVARIENBERGE 925 W. KLFT VOM EINGANGE

VIEW OF MOUNT CALVARY. PART OF GROTTO WHERE LIZARD-LIKE FISH ARE FOUND 925 KLFTr OR FATHOMS FROM THE ENTRANCE



NORTH OF ENGLAND INSTITUTE
OF
MINING ENGINEERS.

MONTHLY MEETING, THURSDAY, FEBRUARY 7, 1856, IN THE ROOMS OF THE INSTITUTE, WESTGATE STREET, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The SECRETARY having read the minutes of the Council, and those of the last monthly meeting,

The PRESIDENT, in taking his seat, announced that a letter had been received from Mr. Stephen Reed, of Newcastle-on-Tyne, accompanied with the presentation of a section of the strata sunk through at the King Pit, Sheriff Hill Colliery.

The SECRETARY having read the letter, and after the drawing of the strata was examined, a vote of thanks to Mr. Reed for his present was moved and carried unanimously.

The PRESIDENT then intimated that the only business before the meeting was the discussion of Mr. Dunn's Paper on "Boiler Explosions;" but previous to proceeding with it, he begged to inform them of what had been done in reference to the establishing of the Mining and Manufacturing College. In the first place, he had great satisfaction in adverting to the very encouraging position in which the project was placed by the munificent offer of His Grace the Duke of Northumberland. The letter intimating His Grace's intentions reflected infinite honour upon him, and left no doubt that, with such support and such means, the College would be established upon a most satisfactory scale. The correspondence had already been published in the newspapers, but, in order that the subject might be properly brought before the members of the Institute, he requested the Secretary to read the letters in question.

The SECRETARY then read the following letters:—

North of England Institute of Mining Engineers,
Newcastle-upon-Tyne, 19th Jan., 1856.

Meeting of the Committee of the proposed British College of Practical Mining and Manufacturing Science.

NICHOLAS WOOD, Esq., in the Chair.

Read the following Letter to His Grace the Duke of Northumberland and the Reply of His Grace's Commissioner thereto.

North of England Institute of Mining Engineers,
Newcastle-upon-Tyne, 24th Dec., 1855.

MY LORD DUKE,—I am desired respectfully to request your Grace's favourable consideration of the accompanying prospectus and circular, emanating from the Committee appointed to take the requisite steps for establishing a College of Practical Mining and Manufacturing Science at Newcastle-upon-Tyne.

The want of an Institution of this practical character is greatly felt, its object being, by bringing the resources of Science to bear upon Mining Operations, to economise the cost of production, and also to diminish the causes of the loss of life from explosions of fire-damp and other casualties, which have hitherto rendered Mining so destructive an occupation.

It is expected that the aid of Government will be procured towards the establishment of the proposed College, providing sufficient general support can be first obtained towards raising the estimated sum of £35,000.

After duly weighing all the circumstances it appears to the Committee that the success of this most desirable project may be regarded as depending on the subscriptions of the Lessors and Lessees of Mines, especially upon those of individuals high in position, who possess a permanent interest in the mineral resources of the country, and to whom this circular and accompanying prospectus are therefore addressed, before distribution amongst the public at large.

To your Grace, in particular, it is, for the reasons given, deemed right to make a first application, whilst your Grace's name at the head of the subscription list would, at the same time, materially assist in the raising of the requisite funds, and by initiating the undertaking confer the essential benefit of placing it in a proper position before the public.

And we beg to add, that it would likewise confer an additional benefit to the undertaking, and a great stimulus to its success and efficiency, if your Grace would kindly please to become the Patron of the College.

We beg, likewise, to forward for your Grace's acceptance the three volumes of the Proceedings of the Institute of Mining Engineers for the years 1853, 1854, and 1855, for the profession of the Members of which Institute, the proposed College is more particularly intended to be adapted. Awaiting the honor of your Grace's reply,

I am, my Lord Duke,

Your Grace's very faithful and obedient Servant,

NICHOLAS WOOD, Chairman.

To His Grace the Duke of Northumberland, &c., &c., &c.

Alnwick Castle, 11th January, 1856.

DEAR SIR,—I am desired by the Duke of Northumberland to acknowledge the receipt of your letter of the 10th inst., forwarding his Grace the Proceedings of the Northern Mining Institute, in three volumes, from its commencement, with prospectus of a proposed College of Practical Mining and Manufacturing Science to be established at Newcastle-upon-Tyne, of which his Grace is asked to become Patron, soliciting also his Grace's aid towards the establishment of the Institution in question.

The Duke has been for sometime aware of the intention of the promoters to establish an Institution of the character described, and directs me to thank the Committee for their attention in presenting him with the volumes and documents above mentioned.

His Grace is of opinion that the projected College, if properly established and conducted, is calculated to prove highly advantageous to the Mining Interests of this part of the country, as well as to those of the kingdom at large, and the project has, therefore, his entire and hearty concurrence.

The Duke is aware, from experience, that the permanency of such institutions greatly depends upon the endowment being adequate to carry them properly forward; especially as regards the procurement of suitable and talented Professors, and therefore recommends this subject to the chief and earliest consideration of the Committee.

Entertaining this view his Grace directs me to state that if £15,000 be raised for the endowment he will contribute £5,000 making £20,000, and if £30,000 be raised he will subscribe £10,000, making £40,000 for the like purpose.

The Duke also accepts the honour of becoming Patron of the College, in compliance with the request of the promoters.

As regards the particular locality of the proposed College, and the expediency or otherwise of appending it to, or connecting it with, any existing establishment; the Duke would recommend that these subjects should receive most mature and dispassionate consideration, as the success and permanency of the intended Institution may greatly depend upon the decision.

I am, dear Sir,

Your very faithful Servant,

HUGH TAYLOR.

To Nicholas Wood, Esq.,
President of the Northern Institute of Mining Engineers.

RESOLVED,—That the Chairman be requested to convey to His Grace the Duke of Northumberland, through the medium of His Grace's Commissioner, the respectful and grateful acknowledgments of the Committee for the munificent offer on the part of His Grace, and to express, at the same time, to His Grace, their full persuasion that the conditions on which the offer is based are, as regards the proposed Institution, most beneficial, and such as must ensure the cordial approbation of every friend to the undertaking; and that the Committee will have the honour of further soliciting His Grace's advice and assistance in reference to that part of the subject which is more particularly noticed in the concluding paragraph of His Grace's communication.

That the foregoing letters and resolution be printed and forwarded together with the annexed address to Frances Anne Marchioness of Londonderry, the Earl of Durham, Lord Ravensworth, and to the other Noblemen and Gentlemen connected with the Mining and Manufacturing Interests of Northumberland and Durham, and of the other Districts of the Kingdom.

MY LADY, LORD, OR SIR,

I do myself the honour, in accordance with the Resolution of the Committee, with whom they originate, to draw your attention to the document appended.

The Resolution embodies, it will be perceived, a vote of thanks to His Grace the Duke of Northumberland, to whom application has been made by the Committee for the establishment of a proposed College of Mining and Manufacturing Science, for aid to that undertaking, these thanks being elicited by the very princely and munificent offer on the part of His Grace, which forms the prelude to the Resolution.

It now becomes the duty of the Committee to solicit the support of others, whose desire to promote education and practical science, as well as the material prosperity of these Counties, and of the Mining and Manufacturing interests of the kingdom at large, cannot be supposed to be inferior to that of His Grace.

With this view the Committee venture upon the liberty of transmitting the Prospectus which accompanies this communication, and which will, it is hoped, sufficiently denote and explain the extent, nature, and purposes of the Institution now proposed to be founded, and manifest at the same time the growing necessity for such an Establishment.

I am desired by the Committee to ask you to give these documents the benefit of your favourable consideration; and if, as the Committee venture to anticipate, you shall approve generally of the undertaking and the arrangements proposed for carrying it into effect, that you will favour them with the expression of such approbation, together with an intimation of the extent of such assistance as you may deem such an undertaking to deserve and require, and so enable the Committee to avail themselves of the munificent proposition of His Grace.

Respectfully requesting the favour of a reply,

I have the honour to remain, &c., &c.,

NICHOLAS WOOD.

That Memorials in support of the above object be signed by the Chairman, and presented to Her Majesty's Government, to the Bishop of Durham, the Dean and Chapter of Durham, the Corporation of Newcastle-upon-Tyne respectively, and to the any other Public Bodies connected with the Mining and Manufacturing Interests of the kingdom, soliciting their aid towards the undertaking.

North of England Institute of Mining Engineers,

26th January, 1856.

MY LADY, LORD, OR SIR,—I have the honour to transmit the accompanying documents relative to the establishment and endowment of a College of Mining and Manufacturing Science, proposed to be founded in Newcastle-upon-Tyne or its vicinity; and to respectfully solicit your favorable consideration for the same, and to ask the favor of a reply at your convenience.

I have the honor to remain, &c., &c.,

NICHOLAS WOOD.

The PRESIDENT then resumed by stating that the letters just read, together with the circular, had been sent to every nobleman and gentleman connected with the coal trade and mining and manufacting interests

of the district, and also to the members of Parliament representing the two counties of Northumberland and Durham—and he trusted they would receive the requisite amount of subscriptions to enable them to avail themselves of the munificient offer of the Duke of Northumberland, and that His Grace's liberality would be followed by several of the noblemen and gentlemen of the district. He, therefore, considered that they could not fail in carrying out successfully so very important a measure, and that they would ultimately have the honour of receiving from His Grace the large sum of £10,000. It might be necessary for him to notice that they had received communications from some existing institutions, complaining that they had not in their Prospectus given due consideration to the importance of such institutions in the education of pupils intended for the mining and manufacturing professions. In answer, it had been stated that while fully appreciating the value of the institutions in question, and intending no discourtesy towards them, it as yet was deemed best to pursue, in the establishment of the proposed College, a perfectly independent course, and to keep steadily in view that the Institution was meant to be of a purely practical character. They were induced to adopt a perfectly independent course, in the first instance, because it would thereby be left quite open and free for the Patrons and Subscribers to the Institution to model it as they might think best and most adapted to accomplish the objects in view, and thus to render it of the greatest practical amount of utility. But while the Committee thought that they should, in the first outset, assume such a position, it did not preclude them from hereafter associating themselves with any existing establishment in such manner as the Patrons and Promoters might think advisable, with a view to make the Institution the most efficient in its accomplishment of the objects sought to be obtained. With regard to the remarks of the Committee as to the practical character of the proposed College, as compared with existing establishments, it was the furthest from their wishes and intentions to depreciate the utility of such institutions, and more particularly the Institution of Practical Science in Jermyn Street. That Institution had been, it may be said, established, and had attained its high standing and eminence by the talents and unremitting industry and exertions of the late Sir Henry de la Beche; and he need only mention the name of Sir Roderick Murchison, as the present President, to ensure conviction in the minds of every one that its utility will not suffer in his hands, but that it will be raised to still higher eminence, and become still further practically use-

ful. He had always, individually, looked forward to considerable assistance and support from that Institution; and while pursuing, from their locality, and the intended character of their proposed College, a path of a more purely practical nature, and imparting instruction to the more numerous class of subordinate colliery and manufacturing students, as well as to those of a higher grade, the two Institutions would, he trusted, mutually aid each other in completing the education of all classes of mining and manufacturing students. And if reference were made to the last paragraph of the excellent letter in which Mr. Hugh Taylor conveyed the sentiments of His Grace the Duke of Northumberland, it would be seen that the same line of proceeding was recommended as that suggested by the Committee. The paragraph he alluded to was as follows:—

"As regards the particular locality of the proposed College, and the expediency or otherwise of appending it to, or connecting it with, any existing establishment, the Duke would recommend that these subjects should receive most mature and dispassionate consideration, as the success and permanency of the intended Institution may greatly depend upon the decision."

This was precisely the line of conduct which the Committee were pursuing, not considering it right to fetter in the least degree the ulterior proceedings of the Patron and Promoters of the undertaking. He (the President), thought it necessary to make these observations to show that while they did not at present associate themselves with any of the existing institutions of the country, they at the same time would be glad to co-operate with them in order to promote the establishment of a College best fitted to promote the object in view. The letters and circular had been sent to about one hundred of the noblemen and gentlemen and lessors of coal of the district, and of others connected with the coal trade of the country. They had not yet approached the lessees of the collieries of Northumberland and Durham, they awaited the annual meeting of those gentlemen, when it was their intention to bring the subject before them; and it was likewise their intention to memorialize Her Majesty's Government, hoping they might receive support from that source. They likewise intended making application to the Bishop of Durham, the Dean and Chapter of Durham, and the University of Durham. Such was, then, the state of affairs as regarded the progress made in obtaining support to the establishment of the proposed College.

Mr. DUNN begged to suggest that an attempt ought to be made to interest the people in Scotland as well as that district.

The PRESIDENT—Of course it will be desirable to communicate with the coal-owners of Scotland as well as of other parts of the kingdom for their aid in promoting the undertaking. At the meeting of coal-owners held in London last year, a resolution was passed in favour of it, which was circulated in every coal district in the United Kingdom; and the Committee intend, after obtaining subscriptions in this district, to transmit copies of their proceedings and the amount of subscriptions to the different coal-owners in the several other districts. The Committee thought that if they succeeded in obtaining any considerable amount of subscriptions in their own district, it might act as a stimulus to the coal-owners of other districts to subscribe.

A conversation here ensued respecting the coal trade, when Mr. T. J. TAYLOR submitted that the most satisfactory way to approach that body was, to suggest that so much per ton be levied upon coals, say for example one half-penny per chaldron.

The subject then dropped: after which the following gentlemen were elected members of the Institute—Mr. Wm. Llewellin, Glanwern, Pontypool, South Wales; Mr. John Furness Tone, C.E., Newcastle-on-Tyne; Mr. Fred. Levick, jun.; Mr. Colin Dunlop, of Cwm, Alga, and Blaina Iron Works, Monmouth; and Mr. Robert Hodgson, C.E., Whitburn, Monkwearmouth.

Mr. T. J. TAYLOR presented, for inspection, a specimen of white coal, from the neighbourhood of Bristol, sent to him by Mr. Greenwell.

The PRESIDENT then drew the attention of the meeting to the Paper which stood for discussion, viz., Mr. Dunn's Paper on "The Explosion of Steam Boilers." The subject was one of considerable importance, and had recently occupied much attention in this district in consequence of the frequency of accidents arising from boiler explosions. He should be glad to hear any observations by members on the subject.

Mr. DUNN enquired if there had not been a discussion on the subject in the Engineer's Society in London?

The PRESIDENT replied that there had been no discussion in the Engineer's Society in London lately, but the members were, no doubt, aware that there was a society in Manchester for the express purpose of enquiring into the causes of boiler explosions. He had taken the liberty of writing to Mr. Fairbairn, the President of that Society, to ascertain if they had published anything upon the subject. Mr. Fairbairn, in reply, informed him that no report of the Association for the Preven-

tion of Boiler Explosions had yet been published, but that he had printed a work entitled "Useful Information for Engineers." He (the President) had obtained a copy of it, and considered it a very useful work on the subject of boiler explosions, and also on other subjects.

Mr. POTTER said, that he believed that Manchester was the only place that possessed an institution of the kind to which the President alluded.

The PRESIDENT, in allusion to the work of Mr. Fairbairn, stated, that it gave the rules, and names of officers of the Association, that Mr. Longridge, one of their members, was the Inspecting Officer, that the Association exercised surveillance over a great many boilers, but as yet they had not published any report, neither had they, he believed, arrived at any satisfactory conclusion on the subject. Mr. Fairbairn had gone into the subject at great length in the work alluded to, and every one knew that Mr. Fairbairn was a sound practical man. He classed the Boiler Explosions under the following heads :—

"Explosions arising from Accumulated Internal Pressure,
" " from Deficiency of Water,
" " from Collapse,
" " from Defective Construction,
" " from Mismanagement or Ignorance."

And he arrives at the conclusions—

"1st.—To avoid explosions from internal pressure, cylindrical boilers of maximum form and strength must be used, including all the necessary appendages of safety valves, &c.

"2nd.—Explosions arising from deficiency of water may be prevented by the fusible alloys, bursting plates, good feed pumps, water guages, alarms, and other marks of indication; but above all, the experienced eye and careful attention of the Engineer is the greatest security.

"3rd.—Explosions from collapse are generally produced from imperfect construction, which can only be remedied by adopting the cylindrical form of boiler, and a valve to prevent the formation of a vacuum in the boiler.

"4th.—Explosions from defective construction admit of only one simple remedy, and that is, the adoption of those forms which embody the maximum powers of resistance to internal pressure, and such as we have already recommended for general use.

"And lastly, good and efficient management, a respectable and considerate engineer, and the introduction of such improvements, precautions, and securities as we have been able to recommend, will not only ensure confidence, but create a better system of management in all the requirements necessary to be observed for the prevention of steam-boiler explosions."

Mr. Fairbairn (continued the PRESIDENT), in his pamphlet, repudiates the idea that boiler explosions were caused by the creation and ignition of gas; and, when it is considered that when water came into contact with red hot iron pure hydrogen was generated, and that it was necessary it should be mixed with atmospheric air, or oxygen, to render it explosive; and that it is difficult to conceive how the atmospheric air or oxygen could find their way into the interior of the boiler when subjected to great internal pressure, he could not think this cause could operate.

Mr. DUNN—Yes, but water, upon red hot iron, formed into globules, will not explode. It was a lesser degree of heat than red heat which caused steam to be engendered, and which produced great and sudden pressure.

The PRESIDENT said it was quite true that globules of water placed on a red hot plate of a certain temperature would not produce steam, but the water would remain in a state of globules; but if they allowed the iron to assume a lesser temperature, then the globules would immediately flash into steam, and thus produce sudden expansion. That, indeed, was likely to occur in boilers over-heated, and when the plates became dry. The water within the boiler might be alternately thrown upon, and again thrown off the plates so heated. The globules would then be alternately formed and flash into steam, and this would go on either until the internal pressure became exceedingly great, or until a remedy was applied. But they would see that in such a case throwing cold water into the boiler would not remedy, but probably aggravate the evil, by throwing the water over, perhaps, a greater surface of the heated plates. It was not, therefore, improbable but that some accidents happened from such a cause, for steam would be generated instantaneously on the water reaching the heated plates, and an immense pressure produced within the boiler. He knew an instance of a boiler at Burraton Colliery being safe a few minutes before it exploded, and full of water. Such a cause as that just stated could not have taken place, and no defective plates could be detected, neither was it possible within the time intervening between the examination and the explosion for the plates to become so heated as to cause the explosion. He could not, therefore, account for the explosion, but he was led to think that in a recent case at Hetton Colliery, the explosion was caused by a portion of the plates becoming red hot, although there was a considerable quantity of water in the boiler, and that the

side plates became uncovered with water by one boiler priming into another, and became red hot below the flues. The fire would thus act against the red hot plates, which would be sufficiently heated to form globules and the ebullition of the water throwing it alternately on the red hot plates, and those of a lower temperature, would thus generate steam in flashes and cause the explosion. Unless there were some rapid creation of steam the explosion could not have occurred, as there was evidence to show that the steam-valve was not blowing off, a short time before the accident took place.

Mr. BARKAS—But was not that explosion caused by the sudden decomposition of the water?

The PRESIDENT—No; I do not think it occurred from the decomposition of the water, and if Mr. Barkas referred to Mr. Dunn's paper, in the diagram (at page 9), here Mr. Dunn says, "an experiment was shown by heating a thin piece of iron *red hot* at the point A, and B being kept at a lower temperature, when water was put into the cavity A it did not fly away into steam, but danced about in a globe like quicksilver; but, upon moving it down to the lower temperature of B, it immediately exploded into steam. Hence it is inferred that it is not *red heat* which causes the explosion, but some intermediate temperature."

Mr. DUNN—But with respect to the safety-valve, when the boiler was deficient of water and increased its heat, would the safety-valve indicate the actual state of the boiler? Or, when they substituted heat for steam at the sides of the boiler, would not that tend to do the same thing?

Mr. BARKAS—Certainly not.

Mr. DUNN—But, supposing the water was diminishing, and the heat increasing, would not the valve be affected by the substitute of heat for steam?

Mr. BARKAS—If the pressure was from the inside it must affect the valve.

Mr POTTER—It was well known that they must have a pressure equivalent to the degree of heat.

Mr. DUNN—But would the safety-valve indicate danger?

The PRESIDENT—If the iron of the boiler was of a certain temperature, it would produce a certain temperature of steam; and if the heat of the plates of the boiler was increased, that heat would, of course, increase the elasticity of the steam; therefore, it must increase the pressure, and be indicated by the safety-valve.

Mr. BERKLEY—But if the heat was applied to the steam alone, no water being in the boiler, would not such increase of heat increase the pressure, and to the same extent as if water was present?

The PRESIDENT—No; he believed not.

Mr. BARKAS, jun., was of opinion that the heat outside expanded the boiler plates, and thus the safety-valve was rendered inoperative by causing it to stick.

Mr. DUNN—But, if the water was absent, would the safety-valve represent what was going on?

Mr. POTTER—Yes, if the safety-valve was free in its action.

Mr. DUNN—What he wanted to know was, as to whether or not, when water was absent and heat applied to the steam, that the safety-valve indicated the correct elasticity of steam in the boiler.

The PRESIDENT—There could be no doubt, that if they detached steam from water and applied heat, it would increase its elasticity, and that the safety-valve would indicate such elasticity correctly, all things being in proper order.

Mr. BARKAS—But it was not certain that the same degree of heat applied to steam detached from water, produced the same effect as to steam in contact with water.

The PRESIDENT—The state of our present information on the subject is, that it is not economical to employ heat to steam detached from water to increase its elasticity; but that a greater effect is produced by the same quantity of heat applied in the ordinary way, than if such heat was applied to steam detached from water.

Mr. BARKAS—Yet, throwing water into the boiler would certainly produce a greater quantity of steam than the boiler could stand when it was dry, and the plates red hot. It was well known, that in iron and water, they had two most dangerous ingredients, viz,—hydrogen and oxygen, and the decomposition of water, by iron in a heated state, might give off these gases, and might, therefore, be the cause of an explosion.

The PRESIDENT—If water is thrown on red hot plates and decomposed it gives out hydrogen only, still they wanted oxygen, or atmospheric air to form combustion; but how could they get into the boiler?

Mr. BARKAS—There was a certain portion of oxygen in the water, if all the particles were decomposed and disengaged. It might not be rapid in its transition, but still the particles might unite in such a way, as that when they came in contact with the red hot iron might have the effect of producing an explosion.

The PRESIDENT—The iron absorbed the oxygen. It might be supposed that it was a difficult thing to produce sufficient power by the elasticity of steam alone to throw a boiler into the air; but, if they took a pressure of two or three hundred pounds to a square inch, and apply that to the surface of a boiler, that would at once give a pressure of several tons. Take, for instance, a square yard, which at two hundred pounds per square inch, will give a pressure of one hundred tons, this would produce a sufficient force to throw a boiler into the air. Mr. Fairbairn instances a boiler 30 feet long, 6 feet diameter, with two centre flues, each 2 feet 3 inches diameter, with a pressure of fifty pounds per square inch, as being subjected to an internal pressure equal to 3319 tons, and if the steam, by accident, or otherwise, is raised to 450 lbs., it will have to sustain a force of 29,871 tons. There was, therefore, no difficulty whatever in accounting for steam throwing a boiler into the air.

Mr. DUNN thought it would be an important desideratum to be possessed of some more perfect instruments to give warning of danger, and to denote at all times the quantity of water in the boiler. He had thought about duplicate floats, but after all it was possible that one might stick and the other keep right.

The PRESIDENT—A few minutes before the Hetton explosion, the safety-valve was all right.

Mr. HALL said there had lately come into use a description of whistle for indicating when the water was low in the boiler.

Mr. BARKAS replied that one of the instruments alluded to by Mr. Hall was in use at the Team Colliery, but it alarmed all the neighbourhood when the water got below a proper point.

The PRESIDENT thought all would admit that the subject was very important, as boiler explosions had become more numerous than usual.

Mr. BARKAS was of opinion that it arose from working at a high pressure. Besides, was there not some difference in the quality of iron?

Mr. DUNN.—Yes, there was.

Mr. BERKLEY referred to two boilers connected with each other with a "flap," and said that leaving the feed valve open the one boiler "primed" into the other, and that the boiler which had the flap left open would empty its water into the other boiler.

Mr. DUNN certainly had considered the working of a flap in his paper; but, notwithstanding, he put it to the meeting to say, whether the use of a flap would be of any benefit?

Mr. BARKAS would inform them that the flap had been in use at Kibblesworth, where by an explosion two or three of the boilers were thrown out of their places, and one was blown to pieces. After the accident, they got a "saucer" placed at the top of the boiler to prevent the steam going direct into the pipe. The steam had then to go between the top of the boiler and the plate or saucer, and after that they never observed any priming from either one or the other boilers.

The PRESIDENT said a similar contrivance was adopted in locomotive engines.

The Meeting then adjourned.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

MONTHLY MEETING, THURSDAY, MARCH 6, 1856, IN THE ROOMS OF THE INSTITUTE, WESTGATE STREET, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The SECRETARY having read the minutes of the Council, and those of the last monthly meeting,

The PRESIDENT stated that the routine of business before the meeting to-day, was the discussion of Mr. T. Y. Hall's Paper "On the Styrian Coal Field of Austria," but as that paper had only been in the hands of the members for a day or two, it would not be desirable to proceed with the discussion at that meeting.

He regretted there was no original paper to read at this meeting, for although they had been promised papers by at least three of their members, they appear to have relied upon each other, and hence the disappointment. He anticipated an accumulation at a future meeting.

The PRESIDENT then stated that he had on a former occasion introduced to them a Mr. Beanlands, Civil Engineer, of Durham, who had proposed to obtain the true meridian in the workings of a coal mine, and so enable them to obtain accurate surveys with the theodolite to check the surveys now universally made by the magnetic instruments. He had given Mr. Beanlands an opportunity of pursuing his experiments at Kepier Grange Colliery, near Durham, and he was glad to find that it was likely a favourable result would arise therefrom. He had asked Mr. Beanlands to be present at the meeting to-day, to explain what progress he had made, and to give the members an opportunity of having explained to them the process which Mr. Beanlands pursued in accomplishing that object, and with their permission he would introduce that gentleman to them.

Mr. BEANLANDS then stated that the object of these experiments was, to ascertain whether it was practicable to fix the direction of the true meridian in the workings of a colliery by means of telescopic observations made at the bottom of the shaft. He had first attempted to effect the desired object by observing the passage of stars across the zenith, according to the principle explained by him at a former meeting, and he had made some observations, with this view, on December 10th, from which the direction of the meridian had been approximately determined. He believed that it would be possible, in this manner, to get a determination with considerable accuracy, but the method was attended, in practice, with much difficulty, and the number of cloudy nights, on which no observations could be made, was found to be a great impediment. Considering, therefore, that it would be very desirable to have some other method, by which the true bearing could be ascertained without the aid of astronomical observations, he had, after much study, devised a plan for effecting the same object by observations made upon artificial illuminated marks. Having completed all the necessary preparations, he had tried this second method also at the Kepier Grange Pit, on Feb. 8th and 19th. The result of these experiments was highly satisfactory. On each night the direction of a line at the bottom of the shaft was fixed with reference to the true meridian, and the two determinations were found to agree extremely well. He felt great confidence, both from the previous attention which he had paid to the subject, and from the result of these trials, that this method would afford the means of finding the true bearing with great accuracy, and he believed that it could be put in practice in nearly every colliery in the district, if not in all. And, as it might be applied with great facility, at any time, in the course of a few hours, whenever a colliery was standing, he considered that it was well adapted for general use, either as a means of checking the magnetic bearing, or in order to form the basis of an accurate survey by the theodolite.

An interesting and lengthened discussion then took place: Mr. Beanlands explaining in detail his mode of obtaining the true line of meridian underground, and contrasting it with others which he had tried, and with some suggested by the members of the society. But as the experiments were in progress, and as they would have laid before them the ultimate result, it was deemed premature to embody such discussion in their minutes.

After some other routine business, the meeting adjourned until Thursday, the 3rd April, 1856.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

MONTHLY MEETING, THURSDAY, APRIL 3, 1856, IN THE ROOMS OF THE INSTITUTE, WESTGATE STREET, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The minutes of the Council having been read by the Secretary,

The PRESIDENT said that the first business to be transacted was the election of gentlemen proposed to become members at the last monthly meeting.

The following gentlemen were then elected members of the Institute: Mr. Henry King Sharp, Darlington; Mr. Francis Coxon, Lumley Colliery; Mr. Thomas Shortreed, Newbottle Colliery; Mr. John Carr, Wallsend and Bell's Close; Mr. Robert Wilson, Flemley Colliery, Maryport, Cumberland.

Mr. REID called attention to the propriety of altering the day of the monthly meeting, as he thought Thursday was a very inconvenient day for the members of the Institute. With that object he begged to give notice of a motion, which he proposed to move at the next monthly meeting, for the purpose of considering the propriety of altering the day, and suggested that such notice be printed in the usual monthly circulars transmitted to the members.

Mr. HALL then read a paper, "Statistical Notes on the Coal and Iron Production of the United States," after which the meeting adjourned.

STATISTICAL NOTES

ON

THE COAL AND IRON PRODUCTION

OF THE

UNITED STATES OF AMERICA.

BY T. Y. HALL.

In my Paper "On the Coal Measures of Styria" I treated at length upon the comparative production of coal and iron ore in the British Isles, (alluding, in particular, to the Durham and Northumberland coal-field), and Austria. The subject of comparisons is so interesting, and at once so inexhaustible, that I have deemed it appropriate to devote a separate paper thereto, so without further preface or apology I shall proceed to remark upon the production of the United States, in a similar way to that which I have adopted in the above-mentioned Paper.

THE ORIGIN AND DEVELOPMENT OF THE UNITED STATES COAL TRADE.

The development of the United States' coal trade, next to that of England, presents one of the most interesting results of earnest and assiduous enterprise to be found in the whole history of commerce. At so recent a period as 1820, the aggregate yearly production of the United States was only 365 tons, on an average just one ton per day. In the present year (1855), 7,307,229 tons have been produced, and even this supply is found insufficient to meet the increasing demand, the foreign importation for the year having amounted to about 300,000 tons. In 1821 the American production was 1,873 tons, and in the same year we sent to the States from England 22,122 tons. This was the commencement of the foreign importation. Previously to 1820 the fuel of America consisted almost entirely of wood, although for ages coal seams, cropping out upon the surface, had lain exposed to the naked eye, and England, with all her vast commercial undertakings, was using more than one-half of the quantity she now does annually. This

circumstance, is, however, less remarkable when we consider that various other countries were at that time ignorant of their own resources in this staple product. Austria, for instance, did not commence to render available her spacious beds of coal till a much later date, and the excellent seams which abound in the Styrian district were unworked till a few years ago. Indeed, since she first figured in the market as a coal producing country, her ratio of production has never been equal to what it might, and in fact ought to have been, even for her own use. It would take eight times her present production (or, in point of time, twelve years, even supposing her trade increased in the same ratio as that of America) to gain a position equal to that of the latter country at the present time, and to equal the production of the Durham and Northumberland coal field twenty times that amount, while to get alongside of England she must increase her production seventy-fold. Probably, with the assistance of railways and other scientific appliances of which she is now tardily beginning to avail herself, she may be able to make a-head and in the course of time raise herself in the scale of coal-producing nations to a height to which her mineral resources ought long ago to have elevated her.

Subjoined is a table showing the progressive development of the United States' coal trade from its commencement. It affords a most interesting example of what persevering enterprise may accomplish, while the various statistics given in the paper on Styria will show the result of an over cautious policy, and of a tardy and only partial adoption of those various scientific and mechanical improvements which modern invention has supplied, and which, rightly employed, tend to facilitate commercial operations throughout the world. I have divided the production from the year 1820 into various periods, dating their commencement from the year in which the product for a new district was added to the general consumption, and giving the aggregate of American and Foreign supply and the yearly average of each, together with the general aggregate and average supply from all sources for the specified periods, and appending to these the septennial aggregate and average for the whole time. From these statistics it will be seen that the panic which arose in America in 1839, and continued more or less to depress the coal trade till the beginning of 1844, affected the production only in a slight degree, while the importation from foreign ports during that period will be seen to have visibly diminished; the price of coals over that short period being full forty per cent. less than for many years previous, viz., 14s. 6d. to 22s. 6d. per ton on the average for unscreened coals. The prices kept low while the price of coal was low in England, and became better and better as English coal advanced in price, and while trade in general improved, as will be seen by a reference to the prices of the last three or four years. However, upon this and similar points which may strike the reader, and for a confirmation of his particular views upon which he may wish to consult statistics like these, I must refer him to the table itself.

	COAL TRADE OF AMERICA DURING THE LAST THIRTY SIX YEARS.	No. of Years each.	American Aggregate.	Yearly American Average.	Foreign Importation.	Yearly average of Foreign importation.	Aggregate of all Kinds.	Yearly average of whole Aggregate.
			Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1820	The first year in which coal was taken to the American market was in 1820, when the produce actually did not exceed a ton per day. It was taken from the Lehigh district. No coals were sent from England during this year	1	365	365	....	..	365	365
1821	The next year they obtained from the same district 1,073 tons, and the foreign importation amounted to 22,122 tons	1	1,073	1,073	22,122	22,122	23,195	23,195
1827	From the last mentioned date to 1827 inclusive, the same district produced	6	168,153	28,025	173,751	28,958	341,904	56,984
1828	The next period of one year, 1828, there was added to the general produce 314 tons of semi-anthracite and bituminous coal from the Schuylkill district	1	77,516	77,516	32,302	32,302	109,818	109,818
1831	In the three following years the produce of the Delaware and Hudson Company's mines in the Wyoming region was added to the general quantities	3	463,637	154,545	140,032	46,677	603,669	201,223
1836	The next period takes in the five years ending with and including 1836, and comprises the addition of the Little Schuylkill mines in the region of that name	5	2,473,130	494,626	395,437	79,087	2,868,567	573,713
1838	In 1837 and 1838 the Pinegrove mines were added to the above..	2	1,617,141	809,069	282,533	141,266	1,899,674	949,837
1841	From the last-named years to the end of 1841 an accession to the above-named mines was made in the shape of the Shamokin mine	3	2,642,759	881,270	490,812	166,604	3,142,571	1,047,532
1845	The succeeding period comprises four years, during which time the addition of the Cumberland district to the last named coal producing localities was made	4	6,067,212	1,519,303	355,527	88,881	6,422,739	1,605,684
1850	The returns for the years 1846-7-8-9 and 1850, comprise the addition of the Lykens Valley mines, the quality being semi-anthracite or bituminous	5	15,419,020	3,083,804	879,694	175,938	16,298,714	3,259,742
1853	The Daupn Company's semi-anthracite coals were added to the general produce in the years 1851-2-3	3	15,718,189	5,239,396	629,297	209,765	16,347,486	5,449,162
1855	During the last two years the Short Mountain semi-anthracite coals have been added	2	13,950,727	7,007,229	540,273	270,136	14,491,000	7,245,500
			58,598,922		3,950,780		62,549,702	

SEPTENNIAL AGGREGATE, AMERICAN AND FOREIGN.

	Single Year. 1820. Tons	1821-27. Tons.	1828-34. Tons.	1835-41. Tons.	1842-48. Tons.	1849-55. Tons.	Single Year. 1855. Tons.
American,	365	169,226	1,769,408	5,504,775	14,545,070	36,610,078	7,300,094
Foreign, ...		195,873	409,370	939,746	856,569	1,548,222	287,408
Total..	365	365,099	2,178,778	6,444,521	15,401,639	38,158,300	7,587,502

YEARLY AVERAGE OVER EACH SEPTENNIAL PERIOD.

	1821-27. Tons.	1828-34. Tons.	1835-41. Tons.	1842-48. Tons.	1849-55. Tons.
American.....	24,175	252,774	786,396	2,077,867	5,230,012
Foreign	27,981	58,481	134,249	108,081	221,174
Total of all kinds yearly	52,156	311,255	920,645	2,185,948	5,451,186

	Tons.
American aggregate from 1820 to 1855, inclusive.....	58,598,922
Aggregate of foreign importation, ditto	3,950,780
Aggregate of all kinds, ditto	62,549,702

YEARLY AVERAGE OVER THE WHOLE PERIOD OF THIRTY-FIVE YEARS.

	Tons.
American	1,674,255
Foreign	112,878
Total	1,787,133

PRESENT STATE OF THE UNITED STATES TRADE, 1855.

	Tons.
American	7,300,000
Foreign	300,000
Total	7,600,000

These statistics show that the total American yield for the whole thirty-five years does not exceed the total production of the Durham and Northumberland field for the last four years, while it is seven millions of tons below the produce of the United Kingdom, or only about equal to the yearly yield of England and Wales alone, that of Scotland and Ireland being excluded. They show also that for the seven years ending 1854, the average yield is only about equal to the yearly production of either France, Belgium, or Prussia during the same period. Indeed Scotland produces yearly about as much as America did last year (1855), namely a little beyond 7,000,000 tons. Both these countries import nearly equal quantities from England, viz., 300,000 tons yearly; and France, Belgium, and Prussia import coal largely from this country.

It will also be seen by the foregoing table that the coal trade of the United States at the present day consists of the produce of about ten districts, nine having been added at various given periods since the working of the Lehigh mines in 1820. The quality of the greater portion of the American coal is hard anthracite, as found in Pennsylvania, in the regions of Wyoming, Lehigh, and Schuylkill. The remaining portion is semi-anthracite and bituminous, the former of which is found in Pennsylvania, in the districts Lykens Valley, Shamokin, and Schuylkill; the latter quality being chiefly obtained in Cumberland, U.S. The proportion of hard anthracite to the other qualities is as 6,300,000 tons to 700,000 tons, the foreign importation amounting to about 300,000 tons, as per table.

Professor Eaton has classed the different kinds of coal found in the United States, under the following heads, viz:—First, the genuine anthracite found in the transition argillite; second, coal destitute of bitumen, usually called anthracite but differing greatly in its character from the anthracite found in argillite; third, the proper bituminous coal; and fourth, the lignite coal, which latter is found in a very extensive stratum in the state of New Jersey.

The veins of anthracite have an alternating inclination of from twenty to forty-five degrees, and generally range from north and north east, to south and south west. Fortunately, for the commerce of the nation, they have generally been found in places approachable by water, though not always in the vicinity of tidal rivers. This latter circumstance has greatly retarded the progress of the trade, inasmuch, as easy river transit from the mines to distant markets has been rendered almost impossible, the shallowness of the water preventing their navigation by vessels of sufficiently heavy draught, to make the trade remunerative. The difficulty could no doubt be overcome by the adoption of the project of Mr. R. G. Moore, who proposes to construct iron steamers, with a screw abaft the rudder, carrying 800 tons of coal, with a draught of water when fully laden of only 7 feet aft and 6 feet forward, to run between the ports on the Durham and Northumberland coast and Paris. There is now a Company formed in France, with a capital of three-quarters of a million sterling, for the purpose of carrying out the project. These vessels might be made to run either upon the extensive American rivers or canals at low water, and by this means a valuable stimulus would be given to the anthracite trade, and the price of that kind of coal would be materially lessened, as would also bituminous coal, which is much required.

The composition of the American anthracite is similar in many respects to that of Wales, though it contains less bitumen, evolves less heat, and leaves a more slaty substance behind it than Welsh coal. It yields a strong, fixed, local heat, is very durable, and causes little or no smoke, but at the same time it lacks flame, and is deficient in that diffused gaseous action which, for various steam operations where rapid evaporation is desired, is so essentially necessary. The heat which it evolves is of such a contaminating nature that when used for household purposes the fires are confined by talc doors, its effect upon the skin being most unpleasant. In most cases vessels of water are kept boiling on the top of the stove in which it is burnt, so that the steam evaporated therefrom may diffuse itself throughout the apartment and moisten the heated air. It has a beautiful metallic lustre, occasionally shining and splendid, its specific

gravity ranges from 1·33 to 1·48, but on the average is not more than 1·44. Its structure is generally compact, sometimes massive, and not unfrequently slightly laminated. From seventy-six to ninety-four, or on the average eighty-five per cent. of carbon enters into its composition, and the colour of its ashes varies with the different localities. Thus, in Northampton and Schuylkill counties their colour is white, but as we proceed eastward towards the Susquehanna river, it changes to a light yellow or pale orange, while the quantity of both ashes and carbon, as well as the softness of the coal, is considerably augmented.

The following table gives the result of analyses of anthracite coal taken at random from some of the districts alluded to in the preceding pages :—

Region or District.	Mines.	Structure, Texture, &c.	Colour of Ashes.	Analysation.			
				Volatile Matter.	Carbon.	Ashes.	
Lehigh	Saminte	Structure dense, laminated; fracture smooth, somewhat conchoidal; colour metallic black; lustre splendent	White	6·60	87·70	5·70	100
Schuylkill	Tamaqua	Texture nearly compact, somewhat slaty; fracture conchoidal; greyish or iron black; lustre splendent; specific gravity 1·57	White	5·03	92·07	2·90	100
Pinegrove	Sharp Mountain	Texture laminated; grey black; fracture splintery; lustre splendent; specific gravity 1·54	White	7·15	80·57	3·28	100
Shamokin	Snyders	Structure massive, compact; fracture laminated; beautifully irridescent	White	6·10	89·90	4·00	100
Wyoming	Lucerne	Texture compact; iron black; lustre splendent; fracture conchoidal; specific gravity 1·40	White	7·68	88·90	3·49	100

Schuylkill appears to have increased its production during the past year more largely than any of the districts. Of the whole supply of anthracite—6,157,569 tons—it has furnished 3,396,036 tons, or nearly 300,000 tons more than half. Last year the increase was proportionately large, namely, 2,986,670 tons from Schuylkill county to 5,847,369 tons from all other sources. Since 1820, when only a ton per day for the whole year was brought into the market, the total production of anthracite coal amounts to 54,990,034 tons, of which quantity Schuylkill county has furnished 28,509,159 tons, or upwards of 2,000,000 of tons more than all the other anthracite districts put together. But even over so long a period as thirty-five years, the total production in this district —the largest coal producing region in the United States—is ten millions

of tons less than the English yearly production. 144 collieries and 104 firms are comprised in this region, the highest number of the former held by any one firm being five, while ninety firms have only a colliery each. Of these, seven firms shipped only one-third of the supply, or 1,072,092 tons; twenty-five firms shipped nearly two-thirds, or 2,222,707 tons; and thirty-six firms shipped the whole supply except 797,083 tons.

I have entered thus largely into the particulars of the production of this district, inasmuch as it is the largest coal producing county in the States, and, therefore, presents a more accurate idea of the trade of the country than any other which I could select, and, also, because in my last paper I introduced similar particulars of the production of the Durham and Northumberland field, to which these statistics will afford an interesting, and, at the same time, a fair comparison. I might go on to analyse the figures which represent the supply from the other districts, and they would present many features of interest to the members of the Institute, but the particulars of the Schuylkill region approximate so nearly to those of the whole of the coal producing districts of the United States, and present data upon which to base calculations for most of the other regions specified in the table of so correct a nature that I believe they will amply suffice.

The Schuylkill coal field, as I have said before, is situated in the state of Pennsylvania, and these statistics serve to show the vast mineral importance of that state as compared with some of the others. Pennsylvanians have not been slow to appreciate the superior advantages of their native state in this respect. From time to time they have put forth the most ridiculously exaggerated statements as to its resources in the article of coal, of which the following paragraph is too rich a specimen to be omitted. It is extracted from the *Harrisburg Intelligencer*, a Pennsylvanian newspaper, in which it appeared in the year 1841.

"But we have not only anthracite, but, according to our State Geologist, more bituminous coal than all Europe! Our state canals intersect this bituminous coal field in all directions. All Europe contains about 2,000 square miles of bituminous coal land: Pennsylvania has 10,000 square miles, or 6,400,000 acres. It is estimated by our State Geologist that the great western bituminous coal field of Pennsylvania contains *three hundred thousand millions of tons!* Ten thousand times more than England, Scotland, Wales, and Ireland."

The "State Geologist" is doubtless a very clever and ingenious arithmetician, and fills his office with eminent satisfaction to his employers, who, no doubt, implicitly rely on his estimates. Some of us, however, who know something of the matter by practical and personal experience, may be allowed to form our own opinions, which are, that the "State Geologist's" estimates only furnish another proof of the questionable veracity of the aphorism that "figures cannot lie." Allowing his figures with respect to the extent of these Pennsylvanian fields to be correct, I think it will be found that 700 square miles of the coal district of our own Durham and Northumberland field, already considerably worked out, and the duration of which I estimate at not longer than 300 years, at its present rate of working, is worth as many sovereigns as the

whole extent of the Pennsylvanian field is worth dollars. That is in respect to the value of the perpetuity of the two districts. The value over and beyond 70 to 100 years purchase is not worth mentioning. Supposing we take all England, the relative value of the coal of the two countries is still more apparent in favour of our own country.

But to return to our statistical statements of the general produce of the States.

Besides those included in the table, there are two or three other districts which have not yet begun to figure conspicuously in the market, but which, nevertheless, add slightly to the general produce. I estimate the omitted quantity at, to say the most, not more than 150,000 tons per annum. One of these districts, situated on the James river, near Richmond City, Chesterfield County, Virginia, and called the Black Heath, Midlothian, and Cloves Hill district, is one which may eventually become of great importance, particularly for sea sale from this river to different ports, as it is nearly 140 miles nearer tidal water than any other, the distance between it or those two districts and the James river being only 12 miles. By the extension of the Richmond and Danwell and the Peterborough and Richmond lines of railway to a point lower down on the James river, called Warwick, an extra distance of only seven or eight miles, ships of 1,000, instead of 200 tons burthen, as at present, could be brought within easy access to load coals from drops and depôts, thus benefitting not only the coal owners, but the city of Richmond, and, in fact, the whole state of Old Virginia. Part of the coal measures of this region are found upon the solid granite,* there being no intervening carboniferous strata or millstone grit, such as one meets with in sinking pits in this and other countries, indeed I found no carboniferous limestone anywhere in those coal measures, although in some places I had pits sunk down to the granite, a distance of 900 feet. The measures consist principally of a seam of bituminous coal, varying from eight to thirty feet in thickness.† The sill below the coal, in these pits to which I have referred, is about a thousand feet below the surface, is very uneven, in consequence of its proximity to the granite, and rises at a great angle

* If, as geologists assert, coal layers are beds formed by the decomposition of immense forests, how could the latter find sufficient nourishment to thrive, and ultimately lodge so as to form solid coal seams to a thickness of 40 feet on the firm granite? I am aware that this objection will be met by an argument founded on the supposition that forests have drifted into this position. However, supposing that to be the case, it requires no slight stretch of the imagination to account for the irregular position and uniformity of the seams, particularly those of France, Prussia, and Belgium. Upon this supposition some geologists are advancing a theory to the effect that the drifting of the Ohio and Missouri is accumulating and forming coal on the spot where these rivers debouch into the Gulf of Mexico. So far as I can judge, if we wait till coal is produced by sand and wood drifting in this manner, we may rest contented till doomsday.

† In the stratification of one of the pits belonging to the Blackheath Company, with which I am largely connected, about 600 feet below the surface and 200 feet above this coal seam, there was found a thin stripe of white mineral called "oil stone," which produced a sort of liquid oil in inconsiderable quantities, and gave out a brilliant flame; it was of a whitish colour, and is probably identical with the modern, so called, "white coal," which Mr. T. J. Taylor produced at our last meeting, and about which he promised to obtain some particulars from Mr. G. C. Greenwell.

—from 1 in 2 to 1 in 3 or 4—until both it and the granite crop out at the surface. Professor Rogers gives the following as the result of an analysis of this coal:—

Carbon	66·50
Volatile Matter	28·40
Ash	5·09
	100·00

A second district is situated at Ashland. It was first opened in 1854, when three firms shipped the *enormous* quantity of 17 tons 8 cwt. This may seem a ridiculously low amount, but, as was said at the time, "though the shipments were *small*, the operators or firms were *big* in faith." This year I find four new firms added to the trade of that region, and the total quantity shipped 125,475 tons—a most encouraging increase. Additional facilities for transport are being opened out every few months, and probably by next year we may find the Ashland supply placed in the yearly tables at no mean figure.

Another of the omitted coal districts is that of the Alleghany field, in McKean county, and distant about 3½ miles from the junction of the Alleghany River and Potato Creek. Its length is not less than 750, and its breadth more than 180 miles; its superficial area being estimated at an enormous number of square miles. It has not as yet been worked to any considerable extent; but from Dr. Salisbury's report, now before me, as to the superior quality as well as magnitude of its resources, I have reason to believe that the time is not far distant when this district may be most successfully and profitably explored. The coal is good, one seam consisting of excellent cannel, and is peculiarly suitable for gas purposes. A piece of this coal in my possession when ignited burns like a candle.

But, besides these, we know that vast beds of coal exist which, at present, have been in a measure untouched. In Arkansas, in Rhode Island, and Massachusetts, east of the Rocky Mountains, beyond Fort Laramie, and at Bellingham Bay, in Washington territory, immense and inexhaustible coal fields have been discovered. There is also a small field in Michigan, which from its low and flat position will not probably be rendered productive at present, yet, from the great advantages it possesses by its proximity to the navigable waters of Lake Huron and other northern lakes, it is likely that in the course of a few years it may become available.

Full one-half of the total produce for the last five years—less, on the average, than 5,600,000 tons—has been consumed in iron manufactures, leaving about 2,560,000 per year for other purposes, throughout the United States, which when we find thirteen States out of 38 containing coal beds to the enormous extent of 133,332 square miles, is a mere bagatelle. The thirteen States I allude to are, Virginia, Illinois, Pennsylvania, Ohio, Kentucky, Indiana, Missouri, Michigan, Tennessee, Alabama, North Carolina, Georgia, and Maryland, which have an area of 611,511 square miles. The remaining 25 States contain 2,421,949 square miles, making 3,033,460 square miles, and the production of coal in the United States, 7,307,229 tons yearly, would average, if equally distributed over the whole extent of country, about 2½ tons of coal yearly for every square mile, or after deducting the quantity required for iron

purposes there is only one and a quarter tons of coal for every square mile of the whole territory, or, as every square mile is 640 English acres, less than nine pounds of coal to every acre of land throughout the United States, or about a quarter of a ton to each individual yearly.

The amount of labour employed in the production of coal in the States in 1840 was 6,811 hands, or nearly half the total number engaged in mining operations throughout the Union. Of these 4,775 belonged to Pennsylvania alone. The aggregate production of coal in that year was 865,414 tons, or about 127 tons to each individual. I have not been able to ascertain the exact number of labourers engaged in mining operations during the past year, but, supposing the relative proportions of individual production and the general produce to be the same as in 1840, we have about 57,480 operatives employed in the production of 7,300,000 of the United States coal through the year, while in the Durham and Northumberland coal-field during the same period, according to the extremely liberal calculation of Mr. Hunt, or my own, which it will be seen is even less, we find (*see page* 68),* 36,624, or 55,124 individuals producing more than double the quantity. The latter quantity includes sailors and whippers in London. Thus another proof is added to many already adduced, that whether as regards operative skill, mechanical appliance, or capability of production, England (or even Durham and Northumberland alone), is at the top of the list of coal producing countries.

The price of labour in America at present is much the same as it was a short time after the coal trade of that country began to flourish, and considerably higher than that which is now paid in England; white labour at all times being scarce and costly. Negro labour might be obtained for less than the present English price, viz., as low as £20 per year, besides rations, clothes, insurance for risk in fiery pits, &c., such as those of Blackheath and Midlothian, for there are very few American pits which contain inflammable gases. The price of labour by the piece in England has not undergone much change during the period over which our comparison extends. During that time we have made great reductions by mechanical improvements, and are still doing so daily. When there is a great demand, or a great depression, there is of course a proportionate fluctuation; as, for instance, during the last few years, coal having been comparatively speaking high and in good demand, wages have been somewhat higher than usual. Just now, however, prices being a little lower, wages are also coming down.

Iron has been produced in the territory now known as the United States for as long a period as 140 years. It was first discovered in Virginia in the year 1715, but until the commencement of the present century it had not been worked to any extent. In fact its manufacture was prohibited by our Government, influenced no doubt by the jealousy of the English proprietors, who apparently saw in the extension of this important branch of commerce, the utter ruin of the monopoly which at that time they possessed. The question of the propriety of allowing the British American Colonies, as they were then called, to manufacture and export iron was agitated during many successive years after their immense resources in that article had been discovered. At length in the year 1750,

* Equal 400 tons per individual.—(*See Appendix, Vol. III.*)

the Government yielded, to some extent, to popular opinion, inasmuch as they allowed the importation into London of British American pig and bar iron free of duty. The colonies were still, however, prohibited from manufacturing their iron. This oppressive enactment continued in force till within ten years of the revolutionary war, since which time, of course, the legislation of the English Government over products of these States has ceased to exist.

The principal varieties of iron ore found in the States are the magnetic oxide, brown hematite, and the argillaceous oxide, found in Pennsylvania; the brown hematite and bog ore, largely prevalent in the State of Connecticut, the magnetic, specular, and argillaceous oxide found in New York, and the magnetic oxide of New Hampshire. Of these the varieties most in use are the argillaceous and magnetic oxide and the brown hematite.

Most of the thirty-eight States contain, to a greater or lesser extent, valuable iron ores. It is in Pennsylvania, however, that they are principally worked, more than one-half of the whole quantity of iron manufactured being made there. In the article of coal Pennsylvania is the Durham and Northumberland, in iron it is the Staffordshire of the Union.* Thirty or more out of the fifty-four counties of which the State is composed, are said to possess large resources of iron, and according to the modest system of computation adopted in America, and, as we have seen before, by the Pennsylvanians in particular, the extent of the iron measures in that State is something more than that of all the rest of the world. Nevertheless it is not a little singular that we export an immense quantity of iron into that very State.

In the James river district, in a small estate of about 200 acres, belonging to the Blackheath, or English Company, large quantities of iron ore are found, and if two or three furnaces were erected in the district and worked regularly, more of the bituminous coal, which it affords, would be required yearly, than has ever been produced over the same period by all the working pits in that district, thus showing how highly important the one trade is to the other. The iron has not hitherto been much worked. Its quality is very rich and beautiful, and it might be turned to profitable account. A small quantity of the Blackheath, Midlothian, and Chesterfield ore, forwarded by me to Professor Rogers, of Charlesworth, U.S., was analysed by him with the following results:—

Peroxide of Iron	85·25
Silica	4·25
Alumina	4·00
Water combined	6·50
Gas	1·00
	100·00

* The iron at present made in Durham and Northumberland is nearly on a par with the quantity manufactured throughout the United States, whilst Scotland exceeds the quantity produced in that country by nearly 100,000 tons. Even South Wales, or Staffordshire, is in excess of the production of America, as will be seen in my previous paper on the "Coal Measures of Styria," page 59.

A second lump gave the following :—

Peroxide of Iron	69·80
Alumina	2·67
Silica	11·90
Carbonaceous matter	3·40
Water and Gas	12·23
	100·00

In connection with this same company's workings and between the Midlothian and Blackheath pits and the James river, at a place called Sallés pits, in the said estate, iron ores are found, in stratified beds twenty feet thick, and also in nodules. Part of the ore is a hard, heavy, red hematite, and frequently of a cellular texture. Whilst I was sinking a pit to this ore and the two or three coal seams below it, at the slight depth of twenty or thirty yards I came upon a seam of what may be termed natural coke, three feet thick. It was hard and had every appearance of roasted hard cannel coal.

In the Alleghany coal-field, iron ore is also met with in considerable quantities; and though at present not much worked, it is stated that it might be produced, by Whipple's new process, at a maximum cost as follows :—

Estimated Cost of working One Ton Pig Metal, by Whipple's new process :—

	Dollars, at 4s. 2d. each.	
Three hands to each furnace, at 2 dols.	6·00	
Supplying 3 tons of Ore	1·50	
" 6 " Coal	3·00	
Board of 3 hands	0·75	
Wear and tear, at 20 per cent. on cost	0·83	
Interest on Capital	0·26	12.39
Transportation to market	6·00	
Storage and Commissions	7·10	13·10
This gives the cost of 1 ton of bloom iron		25·46
Value of 1 ton when sold		60·00
Estimated gain per ton		34·54

	English Money.		
	£	s.	d.
Or, cost per ton	5	8	2
Estimated Selling Price	12	10	0
Ditto Gain, per Dr. Salisbury's Prospectus	£7	1	10

The above estimate has been made in relation to the cost of working the iron ore, and its value.

The price of American pig iron in 1840, according to the official returns,

was £6 5s. 4d., whereas, in England, the price was scarcely half that amount. The same relative proportion in the price of the iron of the two countries has existed from the commencement, and still continues, and I have never heard of any large profits being made by American manufacturers, even at that high price.

According to the specific gravity, as shown by Dr. Salisbury's experiments, a layer or stratum of the argillaceous iron ore, 18 inches thick, contains one ton to the square yard; this gives 4,835 tons to the acre, or 4,835,000 tons to the 1000 acres. Salisbury's analysis gives the strength of the ore at about 43 per cent.: making a reasonable allowance for waste, it will be safe to call it 32½ per cent. This gives 1,611 tons of pure iron to the acre.

Carboniferous limestone is found in large quantities underlying and interspersed throughout the coal beds of various States. This, as is well known, is important to the manufacture of iron, as where limestone is situated at a long distance from the ores, manufacturers have been compelled to have recourse to very indifferent materials for flux; in some cases to such refuse as oyster shells.

The great bulk of the American pig iron is made in Pennsylvania with anthracite coal, part is made in Cumberland with bituminous coal, and some in Virginia with charcoal. British North America has also good ores for coal and iron, and would afford ample scope for English enterprise when iron is profitable in that country or in the United States. In Nova Scotia, one of our flourishing North American colonies, where both bituminous coal and charcoal are plentiful, iron ores of great purity and in great abundance have been found. Our government has largely availed itself of the resources of the colony, on account of the iron being made with charcoal, which renders it much stronger than that in ordinary use, and makes it, therefore, invaluable for mixing with other kinds of pig metal in the manufacture of implements of war, chain cables, &c. Since last summer the government has bought up all the stock in this country belonging to the Acadian Company, Nova Scotia, having become well convinced of its superior excellence. The ores of our own island, particularly those of Northumberland, Durham, and Yorkshire, situated as they are in the midst of a cheap, suitable coal and coke district, which may be worked for centuries to come, have long rendered her independent of foreign countries for a material which tends greatly to consolidate her position as a first-rate European power; and the fact of this iron being found in our own territory adds another to the long list of proofs that England possesses resources in this staple product unequalled in value by those of any other nation in the world, and for this reason, added to the fact of the immense capital which her manufacturers have invested in the trade, she may now justly claim pre-eminence over the whole world.

It is really a matter of great surprise to me that America, possessing the immense resources of coal which I have endeavoured to define, should persist so long in using wood as fuel. Previous to 1840, when coal was 25s. a ton on board ship, exclusive of freights to distant markets, and wood could be got almost for the trouble of cutting, their preference for wood was not so much to be wondered at, but now, when it has fallen to about 14s. or 15s. per ton, only about half the price, I am at a loss to explain

the reason for so general a disuse of it. On no other supposition than that of the want of capital in the trade, or of prejudice and established custom, am I able in any degree to comprehend the matter. When coal can be got at 15s. a ton, which is double the price of other countries, such as England, Prussia, and Austria, I am convinced it is as cheap, or cheaper, than wood for steam and other purposes, especially when we consider its portability and durability, and take into account the more concentrated body of heat which it evolves in burning, as compared with wood; it is, indeed, superior in all respects, as the experience of every English manufacturer abundantly proves. Objections have and may be raised against its price, and, doubtless, the rate at which it is at present sold, low as it may appear, presents a somewhat formidable obstacle to its universal adoption; but the way to cheapen it is not to abandon its production, on the contrary, no effort should be spared to work it effectually, and, if the labour employed in the preparation of wood were transferred to mining operations, I confidently assert that coal would be found, in all coal producing districts, to be the more advantageous of the two. Coal would then be cheapened*, as it naturally must be in the long run, while the tendency of wood is to become dearer. These remarks apply to France and Belgium, where the cost of producing coal is more than double that of England, as well as to the United States. The more extensive the consumption of wood the more costly will it become, and if coal had not been used to some small extent during the last fifteen or even thirty years, the Americans would have found that by this time wood would have grown much more expensive than it is at present. I cannot conceive that an enlightened liberal people like the Americans will maintain for any lengthened period the opinions they now seem to hold with respect to the relative merits of wood and coal; the experience of the whole manufacturing world demonstrates the immense superiority of mineral fuel, and surely the Americans will not persist in keeping up antiquated customs and fighting against such indisputable authority. It will not do to urge the example of France, Austria, and other continental countries, where, although not much used at present, we all know that coal might be more profitably and more advantageously employed in all large commercial operations than wood, cent. per cent. and more the difference in favour of coal. Rent of coal in America is generally from one to two cents per bushel, which is equal to 1s. 3d. to 2s. 6d. per ton, and materials (except wood), are also generally double the price of English.†

* For I see no good reason why the working charges in America should continue to be double those of England, or about as 3 is to 1½ dollars in America, or as 13s. 6d. in America, is to 7s. in England.

† To my own personal knowledge coal working charges are considerably lessened, and the leading charges in several cases alone have diminished from 200 to 300 per cent., since 1840; and, as leading necessitates labour to a very considerable extent, I do not see why it should not follow that the price of labour generally will undergo diminution, either by the application of mechanical contrivances such as coal cutting machines, which I am satisfied will soon come into use in this country, and for which the nature of American coal is suitable, or by some other means. It will be almost a natural consequence of an increased demand for coal that such appliances should be made use of not only in that country, but in all other countries, thus increasing production and cheapening the sale of the staple article coal.

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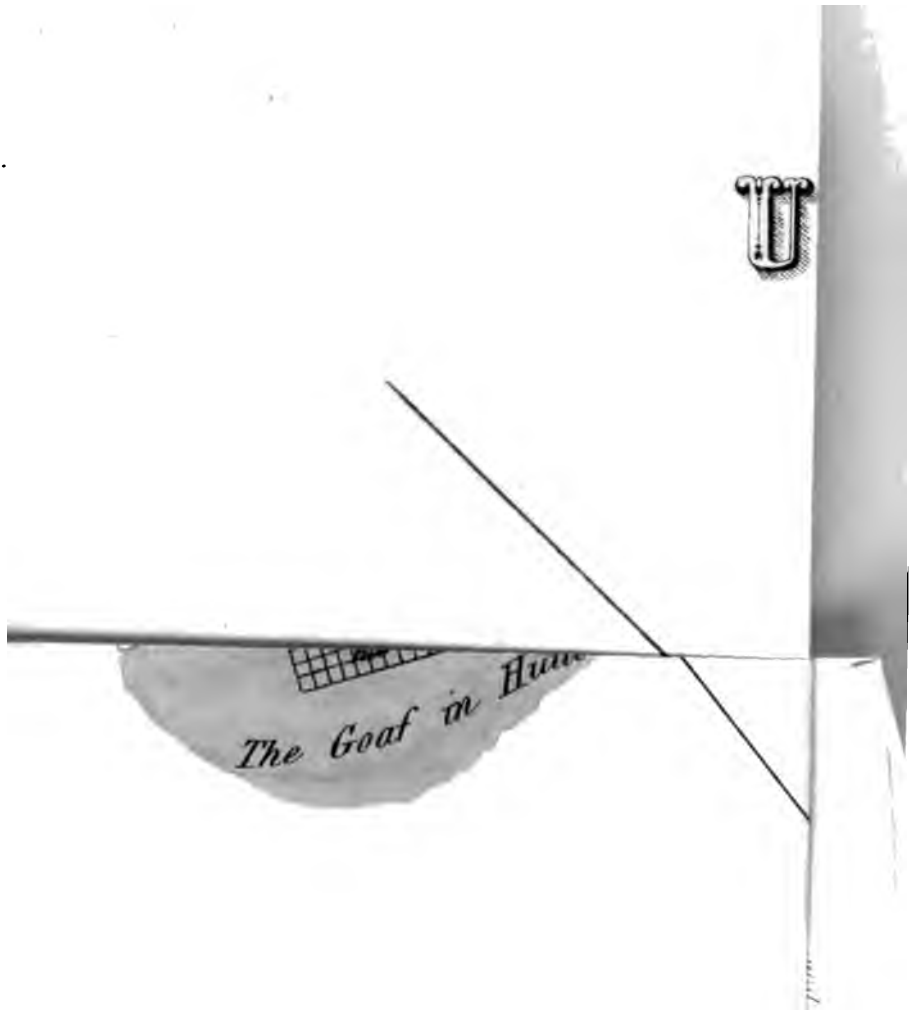

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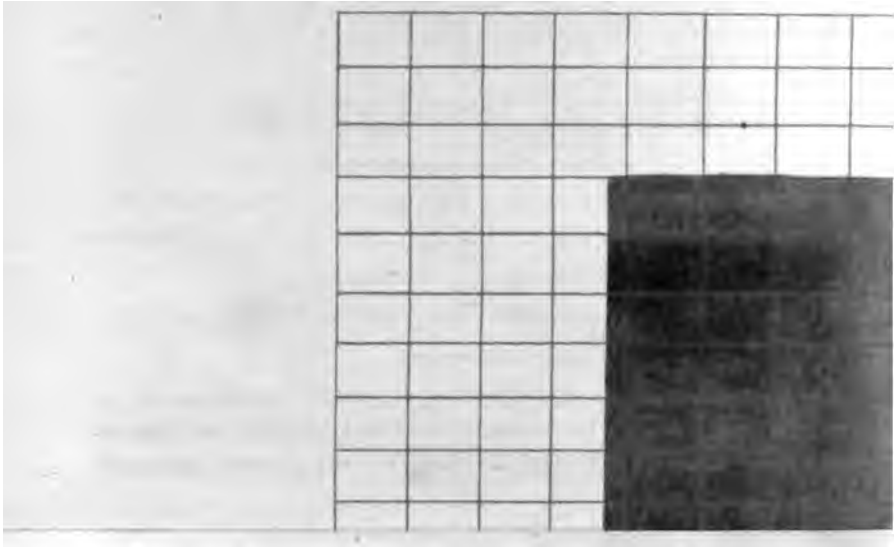


NORTH OF ENGLAND INSTITUTE
OF
MINING ENGINEERS.

MONTHLY MEETING, THURSDAY, MAY 1, 1856, IN THE ROOMS OF THE INSTITUTE, WESTGATE STREET, NEWCASTLE-UPON-TYNE.

T. J. TAYLOR, ESQ., ONE OF THE VICE-PRESIDENTS, IN THE CHAIR.

The CHAIRMAN, on taking his seat, apologized for the absence of the President, who had gone for a short time to the Continent; he hoped he would soon return and resume his functions with renewed health and vigour.

The minutes of the Council having been read,

The CHAIRMAN briefly adverted to the recommendation alluded to in the minutes, of changing the day of the Monthly Meetings from Thursday to Friday. It would be recollected that Friday was the original day of meeting, and it occurred to him that it was a pity it had been changed; the recommendation, however, if agreed to, would bring it back again, but the motion would have to be postponed in consequence of a rule prohibiting any constitutional alterations being made except at the General Annual Meeting. In the meantime the members had time to consider the matter.

Some conversation ensued respecting the relative suitableness of the days, after which the subject dropped.

The following gentlemen were then elected members:—Mr. John Brown, Whitwell Colliery; Mr. William Sewell, Gateshead.

The CHAIRMAN next enquired if there was any Paper for discussion, upon which

Mr. M. DUNN, in reference to the Paper of Mr. Hall, begged to remark

that when members gave statistical details in their respective Papers they should also give the authority for them.

The CHAIRMAN said it was not the legitimate province of the Institute to accept such statements, even with authority, unless what was given was within the personal knowledge of the writer himself. Mr. Dunn had referred to Mr. Hall, but as that gentleman was not present they could not go into the subject further, if, however, any one had observations to offer on the Paper he would be glad to hear them.

The CHAIRMAN, after a pause, finding no one inclined to comply, said the next business was the reading of Mr. Elliot's Paper "On the Effect produced upon Beds of Coal by Working away the Over or Underlying Seams," which Paper was accordingly read by the Author.

A Paper "On the Relative Position of Upcast Shafts and the Loss of Temperature of the same," by Mr. James Longridge, was then read by the Chairman in the unavoidable absence of Mr. Longridge.

A communication was read respecting "The Mode of Constructing Safety Valves," from John Hair, smith, Shotton Colliery.

Mr. DUNN presented "The Civil Engineers' Report on the Subject of Explosions of Steam Boilers," by W. K. Hall; also an account of "Hall's Patent for the Prevention of Boiler Explosions." A boiler float, with steam whistle, was also submitted for examination by Mr. Robert Watson, High Bridge.

The meeting then adjourned.

THE EFFECT PRODUCED
UPON BEDS OF COAL
BY
WORKING AWAY THE OVER OR UNDERLYING SEAMS.

BY MR. GEORGE ELLIOT.

From practical observation in the management of various extensive collieries during several years, I discovered that extraordinary phenomena were presented by the working away in different rotation seams of coal when overlying one another, and at various depths from the surface.

I shall endeavour, and as briefly as possible, to state the different effects I have found produced upon the underlying seams of coal where the upper seam has been first worked out, and shall, therefore, confine myself to a description of the phenomena exhibited in three mines, at the different depths of 80 fathoms, 180 fathoms, and 280 fathoms from the surface, and where the mode of working had been precisely similar.

I propose to deal with the deepest first, viz., the Monkwearmouth Colliery, where my attention was first arrested by what appeared to me a most extraordinary and unaccountable phenomenon. At this colliery there are two workable seams, the Maudlin seam, at a depth of 265 fathoms, and six feet thick, and the Hutton seam, at a depth of 285 fathoms, and four feet thick. The former seam had been worked several years previously to the latter being sunk to, but chiefly in the whole, leaving large pillars of thirty yards by forty yards, with a five-yard bord, in fact only taking away about one-eighth of the coal, leaving seven-eighths for the support of the roof. A considerable number of these pillars were afterwards removed and a large goaf made. During the formation of this goaf, and when it was about twenty acres in extent, a circumstance

occurred which I here mention, as it may probably tend to throw some light upon the subject under consideration, which was as follows. On one occasion there was a heaving of the bottom and a fissure opened from which a large quantity of gas issued, making a noise similar to the escape of high-pressure steam from a boiler, the gas ignited at a candle and burnt some of the men. Some time after this the pit was sunk to the Hutton seam, which also became extensively worked. Generally the coal in this seam was very easy to work, and produced, in the ordinary working, fifty per cent. of small, through a screen the bars of which were five-eighths of an inch apart, notwithstanding the coal itself was hard and strong, singularly so considering the large per centage of small produced. The roof of the mine was uniformly bad, and required a very large quantity of timber to support it, and labour to keep the main ways open. The coal, in course of working, would not stand to be kirved for juds, (technically termed); when kirved it burst out at every blow of the pick with a crackling of the coal, and the top part of the seam thrown or fallen down as the kirving advanced.

The mine at this enormous depth was at a temperature of 77° Fahrenheit, and exceedingly free from carburretted hydrogen gas, so much so that it was the custom to drive the bord forty yards to the pillar, and the wall thirty yards further, without brattice, and with the naked candle. The heat was such as always to induce a natural ventilation, by maintaining a current of air, which always passed down by the floor of the mine and returned by the roof. I have frequently seen this natural current so strong that it made a lighted candle "swale."

In the progress of working the Hutton seam, the workings advanced to the district immediately under the goaf in the Maudlin seam; and at this point, throughout the whole area, where the coal in the Maudlin seam had been entirely taken away, a most remarkable change took place in the Hutton seam coal. It became hard to work, there was no crackling nor bursting out attending the working of this district, and it could only be worked by the use of gunpowder. The coals wrought were very much larger, and a considerable diminution in the per centage of small (not less than twenty per cent.) was the result. The roof was strong and scarcely required any timber to support it; in fact it was quite like another pit, and the coal, even when worked in the broken or pillar working, was still hard and strong.

The accompanying diagram represents the relative positions of the two workings, the *red* being the goaf in the Maudlin seam, the *yellow* being

the coal immediately under it in the Hutton seam, and the *yellow lines* that portion of the same seam not under the goaf, but immediately adjoining it, and producing the large per centage of small coal.

The next example I have to give is at Usworth Colliery, where there are three seams of coal in course of working, viz., the Hutton seam at a depth of 175 fathoms, the low main 165 fathoms, and the Maudlin seam at a depth of 155 fathoms from the surface. These seams were simultaneously worked. The system of working then adopted was, in the first instance, to work the upper or Maudlin seam, the Low Main next, and the Hutton seam last. It was, however, found that, in the course of a few years, as soon as either of the two lower seams had in the course of working arrived where either of the two seams above had been taken away, the coal under these goaves became so hardened and bad to work that it became a difficulty to induce the men to work the coal, especially in the Hutton seam, which, under ordinary circumstances, was a very tender fragile coal, from its want of size unfit for household purposes, and therefore best suited for gas or manufactories.

In this mine there is a large production of carburetted hydrogen gas, rendering the general use of candles and gunpowder unsafe; and although in some instances double the amount of score price was paid for working the portion of coal under the goaf, yet it was found insufficient to compensate the workmen for hewing it, and it became a question how the seam was to be worked at all.

The accompanying diagram exhibits the large blocks of coal underlying the goaf in the upper seams, which are abandoned as being unworkable. After struggling for a considerable length of time with this difficulty, before I had arrived at the conviction of its cause, (which was only done after repeated instances of the same effects), and observing that though the coal did not make the hissing noise, yet there was a considerable quantity of gas remaining in the hard places, I was obliged to change the system of working this colliery, which was to reverse the order of working hitherto observed, by stopping the upper seams and advancing the lower, so as to work the coals entirely out in them before approaching with the workings in the upper seams.

My underviewer, Mr. Cole, explained to me that in working the lower seam under a goaf in the upper seam, that had been laid down at Jarrow colliery several years ago, a similar result had been met with, which to them seemed unaccountable.

The third instance I now give of the working seams of coal in a

similar manner, at a less depth, viz., 80 fathoms from the surface, is from the Marchioness of Londonderry's collieries. A great extent of the coal there is at that depth, and has been worked extensively in the manner described in the several former instances; and there, as well as in many other similar cases, seams of coal have been worked under my direction, without appreciably shewing any of the effects which have been so strongly evidenced in those mines at greater depths.

The foregoing are a few of the striking results which I have observed in working seams of coal, where the coal in the upper seam had been taken away first.

I shall now proceed to give a few instances of the effects produced on upper seams by the working of the seams immediately below them.

The old fashioned system of working coal in the North of England was in what was called the whole, leaving pillars of adequate or supposed adequate strength to maintain the roof; and not unfrequently this has been done over a considerable area in three or four seams, the quantity of coal taken away being about ⅓rd, leaving ⅔rds. This condition of a colliery renders it very puzzling to the viewer to decide which is the best mode of working the remaining ⅔rds, without occasioning considerable loss of coal by creating creeps, which indeed is almost impossible. If the course of working the pillars in the lower seam is decided upon, as soon as this is done extensively, the subsidence of the roof by the removal of the coal, disturbs the pillars in the upper seams, and a creep is almost inevitable. On the other hand, if, perhaps, the safer course be adopted and the upper seam is taken away first, then the violent falling in of the roof frequently occasions considerable injury to the seam immediately below it, damaging the air-courses, waggon-ways, &c. The injury however, does not always extend in the same degree to the seams below, and I am, therefore, inclined to think that when seams of coal are so situated, all standing in pillars, more merchantable coal can be obtained by working the higher seams first and so downwards.

The improvements of mining science and practical experience will henceforth, I have no doubt, prevent the future occurrence of the condition of things I have just referred to. Modern practice has decided that to leave large areas of pillars, is neither so economical in the working of a colliery nor so safe against accident. The approved practice now being either to work the coal by means of long wall or by large pillars, removing them simultaneously with the working in the whole coal. Again, we have the system of working the lower seam entirely out first before entering the

upper seam. This is frequently done without either much inconvenience or injury to the seam above, although frequent breakers or fractures come up from one seam to the other, when the chief difficulty is to deal with the gas that ascends from the lower seam; this, however, to my knowledge has never been found insurmountable, nor do I think that generally the working expenses of the upper seam are much increased, nor the per centage of small, neither is the size or quality of the large coal materially injured by this mode of working.

In many parts of the country there are certain covenants embodied in colliery leases which prescribe that certain of the seams demised shall be worked first, and shall be worked in a certain manner. From a full consideration of the subject now under notice, it cannot fail to strike every one present, how difficult it is to lay down any fixed rule or system which would guide to the most effectual working of a series of seams of coal, as the two examples I have given at Monkwearmouth and Usworth Collieries most clearly show, that while in the former the working away the upper seam first improved the seam below in every respect, at Usworth the same rule applied rendered the lower seam almost valueless, and at collieries of less depth there is no appreciable effect produced.

Assuming that the phenomena witnessed in the instances cited will prove to be universal at those depths, it would require the mode of working to be varied to suit the circumstances of each case; still it is a most valuable discovery if it should, as I have supposed, affect the whole area of a royalty in the lower beds of coal, by the first working the upper seam (my observations have hitherto been confined to an area not exceeding 30 acres), and a great principle will have been ascertained and established, viz.:—that the lower seams are improved in hardness, in yield of merchantable coal, the roof improved, and all the incidental work, except the hewing, economised by the system.

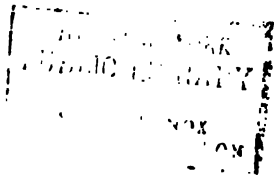
It will then become a question for practice and further experience to determine if it will not be the better way of working collieries, especially of great depth, by excavating the upper seam first, although as a rule the coal is not so strong, and yields more small coal than the same seam of coal would do at a less depth, and, although it might not in itself be so remunerative to the owner to work, still I conceive that the advantage gained by the improved value of the lower seams would fully compensate for the diminished profit on the upper seam. The peculiar result and disadvantage from working the upper seam at Usworth Colliery first will prove to be exceptional, and applicable only to similar situations

where the coal is not required to be worked large, and where the use of gunpowder cannot be adopted.

Upon a careful review of all the circumstances arising out of the consideration of this interesting subject, I am of the opinion that it will prove to be of permanent advantage to deep coal mines to work the upper seams first, and so improve the lower beds in hardness.

The facts and observations described in this paper, will probably lead to some discussion by the members of this Institution at a subsequent meeting, I have, therefore, intentionally withheld the reasons which occur to me as accounting for and explaining this (I believe), hitherto unobserved phenomenon.

As the President will probably appoint a time for the discussion of the contents of this paper, I deem it better to intimate that on that occasion I shall endeavour to show to what cause this extraordinary condition is attributable.



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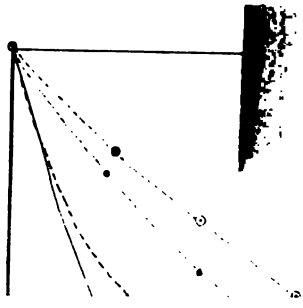

ERRATA.

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read Brick 0·1 thick, ... 3·65
188 " *for* C. A. Brooks *read* C. H. Brooks.

ON THE RELATIVE POSITION OF UPCAST SHAFTS, AND THE LOSS OF TEMPERATURE IN THE SAME.

BY JAMES A. LONGRIDGE.

(1.)—The proper position of the upcast shaft relatively to that of the downcast is a question which, as far as I am aware, is yet open to discussion, and is one which, as it obviously is subject to fixed laws, ought not to be allowed to remain undetermined.

(2.)—In a paper, read before this Institute, by Mr. Greenwell, in 1853, he directs attention to some observations made by him in Backworth Colliery, in 1844, to which I shall have occasion to refer, but which, at present, I only mention to point out the fact that there is still a difference of opinion, or perhaps, I should say, a want of definite opinion on this point, amongst even the most scientific of our practical men. Mr. Greenwell makes use of the following language:—

"Were the necessity, where practicable, of having upcast shafts situated to the extreme rise of a colliery not so universally admitted it would be established by the experience of such facts as those given above."—(Trans. Vol. II., p. 23.)

Here it is evident that Mr. Greenwell has not only arrived at a conclusion in his own mind, but, also, is under the impression that that same conclusion equally exists in the minds of his professional brethren.

(3.)—On the other hand, if we turn to Mr. Taylor's notes upon Mr.

Atkinson's paper, published in Vol. III. of the "Transactions," we find him thus expressing himself:—

"The foregoing principles involve a yet undetermined point in mining—the proper situation of the ventilating shafts."

(4.)—Mr. Atkinson, again, in the Supplement to his elaborate paper on Ventilation, says:—

"It has, I believe, been laid down as a principle, in the Ventilation of Mines, that the upcast pit ought to be situated more to the rise of the strata than the downcast pit, for the purpose of Ventilation. Where the surface of the earth is situated at the same level, at the top of each of the pits, and furnace action is employed to produce ventilation, I disagree with the above principle as a general rule; because, I think it will generally be found that the upper part of the upcast column of air will be so much more heated and expanded than the air in the ascending workings between the bottom of the downcast and that of the upcast pit, that it will give a pressure over equal vertical distances capable of overcoming more than double the ascensional power, so to speak, of the air in such ascending workings, and whatever is to spare beyond this, will be so much added to the general ventilating pressure for an equal consumption of fuel."—(Trans. Vol. III., p. 327.)

The reason here given is somewhat obscurely expressed, but it appears to be something like the following, viz., that in the case of the deepest shaft being made the upcast, the ventilating power of that portion of it which is represented by its excess of length over the downcast is still, in general cases of furnace ventilation, more than double the ventilating power due to the temperature of the workings considered as acting contrary to it; so that it not only counteracts the ascensional power of the workings, but is more than sufficient to impart an equivalent motion in a contrary direction, and by as much more as it can do this, by so much is the actual increase in the ventilation of the mine.

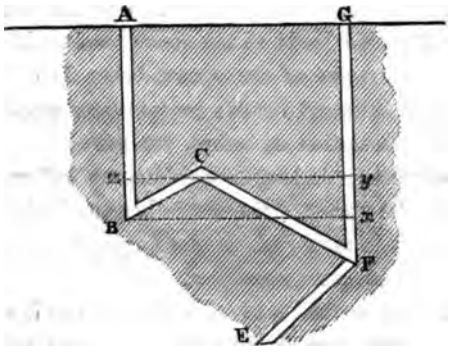
If this be Mr. Atkinson's meaning, I decidedly agree with him, but at the same time, it is desirable that the diversity or indecision of opinion on the subject which has been shown to exist should, if possible, be removed, and the question based upon such formula as may admit of the solution of any case which may occur in practice.

(5.)—I shall first make a few observations upon Mr. Greenwell's paper above referred to, and the results deduced by him therefrom.

In this case, Mr. Greenwell has compared the ventilating powers of columns, not of the same pit under different circumstances as regards the position of the upcast and downcast, but, in fact, of two altogether dis-

tinct sets of workings, of which, it is true, the upcast shaft was the same in both. In fact, referring to his diagram (Trans. Vol. II., p. 32), he compares the ventilation of the system A B C F G, in which the downcast A B was 53 fathoms, and the upcast G F 85 fathoms, with that of

(Fig. 1.)



the system G F E E F G, in which both upcast and downcast were the same length, viz., 85 fathoms; and he arrives at the conclusion that the latter system had a preponderating power of 0·5983lbs. per square foot; but whatever argument this may afford with respect to the superior facility of ventilating dip over rise workings, it clearly has no bearing on the question of the proper position of the shafts.

In fact, to make such a comparison, Mr. Greenwell should have supposed the ventilation reversed in the system A B C F G, viz., that G F was made the downcast, and A B the upcast shaft. Now, in this case, he would have found the difference in weight of the column as follows, assuming the temperature the same as in the case given by him, and adopting his mode of calculation:—

1st.—$G\,F - y\,F = \frac{252 \times (77{\cdot}5 - 43{\cdot}875)}{480 + 45{\cdot}5} = 16{\cdot}124$ ft.

at 43°·875 = at 50° = 16·324 ft.

2nd.—$y\,F = \frac{258 \times (58{\cdot}5 - 43{\cdot}875)}{480 + 26{\cdot}5} = 7{\cdot}447$ ft. at 43·875 =

at 50° = 7·584

3rd.—$y\,x = \frac{66 \times (77{\cdot}5 - 53{\cdot}125)}{480 + 45{\cdot}5} = 3{\cdot}061$ at 53·125 =

at 50° = 3·043

26·901

Now, although this is greater than in the former case where the deeper of the two pits was the upcast, in which case the difference in weight of column was equal to a column of air at 50° of 26·728 feet, yet the differ-

ence is so small as certainly not to warrant any conclusion as to the proper relative position of the shafts.

(6.)—The reason of there being a slight preponderance in this case in favour of the shallow upcast is, that the temperature in the portion of the workings G F is very considerably elevated relatively to the temperature of the upcast, and its effect being favourable to the shallow upcast and contrary to the deep one leads to the above result. But if we suppose the case of the temperature of the upcast being 110° instead of 77°·5 we shall get a very different result: for instance, when G F is upcast, making the same calculation as before, we get

G F upcast—difference in length of column at 50° = 54·89 ft.

And if A B be the upcast, difference in length of column = 44·441 ft.

And the difference in favour of the deep upcast = 54·89 − 44·44 = 10·45 ft., or about 1 lb. per square foot.

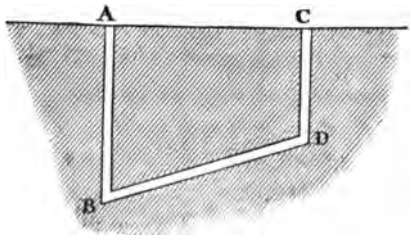
(7.)—It is true that in the case I have just supposed, we would require a greater furnace power than in the case of the shorter upcast; inasmuch as we have supposed that the whole of the column of the longer upcast is maintained at the average of 110°. Whereas it is obvious that with the same furnace power the upper part of this column would be somewhat lower, owing to the conducting power of the shaft robbing the air of some portion of its heat; but making every allowance for this, there would still remain a great preponderance in favour of the upcast G F.

(8).—From this it is manifest that the question is one which depends upon the circumstances of each individual case and that, unless we take these circumstances into consideration, we cannot truly decide upon the proper position of the upcast.

It will be well, therefore, to put the conditions in an algebraic form, so that we may see clearly what are those circumstances which influence this result, and their relative bearing upon each other.

(9.)—I will first suppose the simplest case of the top of the shafts being on the same level, and the workings having a constant ascent from one shaft to the other.

(Fig. 2.)



Let D = Depth of A B.
T = Average temperature of A B.
d = Depth of D C.
t = Average temperature of D C.
D − d = Rise of the workings.
θ = Average temperature of workings.

It is evident that the ventilating column is the difference of weight of the columns ascending and the columns descending, or, if we call ascents positive and descents negative, we shall have, if A B be the downcast, the ventilating power expressed by

Weight of A B ..... Positive.
Weight of B D (in a vertical direction) ..... Negative.
Weight of C D ..... Negative.

Or = Weight of D − Weight of (D − d) vertically − Weight of d, but the weight of a cubic foot of air at 0° of Fahrenheit's scale and 30 inches of mercury

lb.
$= 0{\cdot}08657$ therefore

Weight of D at 0° $= 0{\cdot}08657\ D$

and Weight at T° $= 0{\cdot}08657\ D\ \frac{459}{459 + T}$

In the same way Weight of (D − d) in a vertical direction at θ°

$$= 0{\cdot}08657\ (D - d)\ \frac{459}{459 + \theta}$$

and Weight of d at t $= 0{\cdot}08657\ d\ \frac{459}{459 + t}$

therefore, ventilating power per square foot of surface

$$= 0{\cdot}08657\ D \frac{459}{459 + T} - 0{\cdot}08657 (D - d) \frac{459}{459 + \theta} - 0{\cdot}08657\ d \frac{459}{459 + t}$$

$$= 0{\cdot}08657 \times 459 \left(\frac{D}{459 + T} - \frac{(D - d)}{459 + \theta} - \frac{d}{459 + t} \right)$$

$$= 39{\cdot}74 \left(\frac{D}{459 + T} - \frac{(D - d)}{459 + \theta} - \frac{d}{459 + t} \right) \quad \ldots\ldots\ldots\ldots [1]$$

which may be put under the form $\frac{39{\cdot}74}{459 + \theta} \left(\frac{D\,(\theta - T)}{459 + T} - \frac{d\,(\theta - t)}{459 + t} \right)$

(10.)—If, now, in this expression we suppose D, T, θ, and t, to remain constant, and d to increase gradually, we will have the term

$\left(\frac{D}{459 + T} \right)$ constant,

$\left(\frac{D - d}{459 + \theta} \right)$ decreasing,

$\left(\frac{d}{459 + t}\right)$ increasing.

And, therefore, the value of the expression will depend upon the relative rate of the decrease of $\frac{D - d}{459 + \theta}$ to the increase of $\frac{d}{459 + t}$

Let the expression [1] be put under the form

$$39{\cdot}74\left(\frac{D}{459 + T} - \left(\frac{D - d}{459 + \theta} + \frac{d}{459 + t}\right)\right)$$

and taking the negative portion of this, let us substitute $(d + \delta)$ for d and we get

$$-\left(\frac{D - (d + \delta)}{459 + \theta} + \frac{d + \delta}{459 + t}\right) \times 39{\cdot}74$$

$$= -\left(\frac{D - d - \delta}{459 + \theta} + \frac{d + \delta}{459 + t}\right) \times 39{\cdot}74$$

and subtracting the original value

$$-\left(\frac{D - d}{459 + \theta} + \frac{d}{459 + t}\right) \times 39{\cdot}74$$

we get the increment or decrement of the expression

$$= -\left(\frac{-\delta}{459 + \theta} + \frac{\delta}{459 + t}\right) \times 39{\cdot}74$$

Now, if θ be less than t

$$\frac{-\delta}{459 + \theta} \text{ is greater than } \frac{\delta}{459 + t}.$$

$$\text{and } \frac{-\delta}{459 + \theta} + \frac{\delta}{459 + t} \text{ is negative.}$$

But, inasmuch as the whole of the expression $\frac{D - d}{459 + \theta} + \frac{d}{459 + t}$ is affected by the negative sign, it is evident that the two negative signs combining will render the difference positive as regards $\frac{D}{459 + T}$ and that the result will, therefore, be to increase the amount of ventilating power by

$$39{\cdot}74\left(\frac{\delta}{459 + \theta} - \frac{\delta}{459 + t}\right)$$

$$= 39{\cdot}74\,\delta\left(\frac{1}{459 + \theta} - \frac{1}{459 + t}\right)$$

$$= 39{\cdot}74\,\delta\left(\frac{t - \theta}{(459 + \theta)(459 + t)}\right)$$

(12.)—It has, therefore, been shown that *when two shafts proceeding from the same surface level are united by a uniform series of workings, the ventilation is increased by the increase of the depth of the upcast*

shaft, provided that the mean temperature of the workings does not exceed the mean temperature of the upcast.

In case $\theta > t$ the result is of course the contrary of this, and the ventilating power is decreased by $39{\cdot}74\,\delta\left(\frac{\theta - t}{(459+\theta)(459+t)}\right)$

It may be said that this result is so obvious that it does not require any demonstration. This is true, if we have in our minds only the ordinary cases of furnace ventilation, but it is not so obvious in the case of other systems of ventilation, when it may be quite possible that the average temperature of the upcast shaft may be below the average temperature of the workings, in which case the investigation shows the detrimental effect of increasing the depth of the downcast.

We have also thought it right to enter into the investigation as a means of familiarizing the minds of some who may not be in the habit of reasoning from symbols, with a method which we shall adopt in less obvious cases.

(13)—We will next suppose a case in which the sum of the lengths of the two shafts remains constant, or that at the same time that the upcast shaft increases by δ, the downcast decreases by the same quantity.

The expression [1] now becomes

$$= 39{\cdot}74\left(\frac{D-\delta}{459+T} - \frac{(D-\delta)-(d+\delta)}{459+\theta} - \frac{d+\delta}{459+t}\right)$$

$$= 39{\cdot}74\left(\frac{D-\delta}{459+T} - \frac{D-d-2\delta}{459+\theta} - \frac{d+\delta}{459+t}\right)$$

and subtracting from this the original expression [1] we get

$$39{\cdot}74\left(\frac{-\delta}{459+T} + \frac{2\delta}{459+\theta} - \frac{\delta}{459+t}\right)$$

$$= 39{\cdot}74\,\delta\left(\frac{2}{459+\theta} - \frac{1}{459+T} - \frac{1}{459+t}\right)$$

$$= 39{\cdot}74\,\delta\left(\frac{2}{459+\theta} - \left(\frac{1}{459+T} + \frac{1}{459+t}\right)\right)$$

which will be positive if

$$\frac{2}{459+\theta} > \frac{1}{459+T} + \frac{1}{459+t}$$

that is if

$$\frac{1}{459+\theta} + \frac{1}{459+\theta} > \frac{1}{459+T} + \frac{1}{459+t}$$

but if θ be $> T$ (θ being the temperature of the workings and T of the downcast shaft),

$$\frac{1}{459+\theta} < \frac{1}{459+T} \text{ by } \frac{\theta - T}{(459+\theta)(459+T)}$$

and if $\theta < t$

$$\frac{1}{459+\theta} > \frac{1}{459+t} \text{ by } \frac{t-\theta}{(459+\theta)(459+t)}$$

consequently

$$\frac{2}{459+\theta} > \frac{1}{459+T} + \frac{1}{459+t}$$

$$\text{if } \frac{t-\theta}{(459+\theta)(459+t)} > \frac{\theta - T}{(459+\theta)(459+T)}$$

$$\text{or if } \frac{t-\theta}{459+t} > \frac{\theta - T}{459+T}$$

that is to say the ventilating power will be increased if the difference between the temperature of the upcast and workings divided by 459 + temperature of the upcast be greater than the difference between the temperature of the workings and the temperature of the downcast divided by 459 + temperature of the downcast.

(14.)—If, however, $\theta > t$ we have

$$\frac{1}{459+\theta} + \frac{\theta - T}{(459+\theta)(459+T)} = \frac{1}{459+T}$$

and

$$\frac{1}{459+\theta} + \frac{\theta - t}{(459+\theta)(459+t)} = \frac{1}{459+t} \text{ therefore, by addition}$$

$$\frac{2}{459+\theta} + \frac{(\theta - t)}{(459+\theta)(459+t)} + \frac{\theta - T}{(459+\theta)(459+T)} = \frac{1}{459+T} + \frac{1}{459+t}$$

$$\text{therefore } \frac{2}{459+\theta} < \frac{1}{459+T} + \frac{1}{459+t} \text{ if}$$

$$\frac{\theta - t}{(459+\theta)(459+t)} + \frac{\theta - T}{(459+\theta)(459+T)} \text{ be positive,}$$

$$\textit{i.e.,} \text{ if } \frac{(\theta - t)}{459+t} + \frac{\theta - T}{459+T} \text{ be positive,}$$

but since, by hypothesis, $\theta > t$, and also $> T$, this expression is always positive; consequently, in this case, the supposed variation in the shafts will always diminish the ventilating column. We, therefore, arrive at these results:—1st. *That the effect of the supposed simultaneous varia-*

tion of the depth of the shafts will decrease the ventilating power in all cases when the mean temperature of the workings is greater than the mean temperature of the upcast. 2nd. That when the mean temperature of the workings is less than the mean temperature of the upcast the ventilating power will be increased or diminished according as

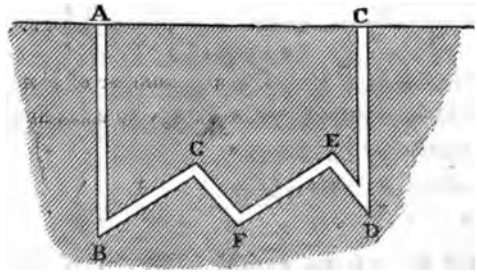
$$\frac{\textit{the temperature of the upcast} - \textit{temperature of the workings}}{459 + \textit{temperature of the upcast}}$$

is greater or less than

$$\frac{\textit{the temperature of the workings} - \textit{temperature of the downcast}}{459 + \textit{temperature of the downcast.}}$$

(15.)—If we now take the case of workings which contain alternate rises and dips, such as the system A B G F E D C, (*Fig.* 3), we may

(*Fig.* 3.)



express the ventilating power as follows, A B being the downcast,—

Weight of A B			Positive.
Weight of B G, in a vertical direction.....			Negative.
Weight of G F	Ditto	Ditto	Positive.
Weight of F E	Ditto	Ditto	Negative.
Weight of E D	Ditto	Ditto	Positive.
Weight of C D			Negative.

And calling D the depth of A B and .. T its temperature.

R_1	vertical height of	B G ..	θ_1	Ditto.
F_1	Ditto	G F ..	T_1	Ditto.
R_2	Ditto	F E ..	θ_2	Ditto.
F_2	Ditto	E D ..	T_2	Ditto.
d	depth	C D ..	t	Ditto.

Then, we get,

$$\text{Weight of A B at T} = 0{\cdot}08657\ D\ \frac{459}{459 + T}$$

$$\text{Weight of B G ....} = 0{\cdot}08657\ R_1\ \frac{459}{459 + \theta_1}$$

&c., &c.

And total ventilating column

$$= \frac{0{\cdot}08657\ D\ .\ 459}{459 + T} - \frac{0{\cdot}08657\ .\ R_1\ .\ 459}{459 + \theta_1} + \frac{0{\cdot}08657\ .\ F_1\ .\ 459}{459 + T_1} - \&c.,$$

$$- \frac{0{\cdot}08657\ d\ 459}{459 + t}$$

$$= 0{\cdot}08657 \times 459 \left(\frac{D}{459 + T} - \frac{R_1}{459 + \theta_1} + \frac{F_1}{459 + T_1} - \frac{R_2}{459 + \theta_2} \right.$$

$$\left. + \frac{F_2}{459 + T_2} - \&c. - \frac{d}{459 + t} \right)$$

$$= 39{\cdot}74 \left\{ \left(\frac{D}{459 + T} + \frac{F_1}{459 + T_1} + \frac{F_2}{459 + T_2} + \&c., \right) - \right.$$

$$\left. \left(\frac{R_1}{459 + \theta_1} + \frac{R_2}{459 + \theta_2} + \&c. + \frac{d}{459 + t} \right) \right\} \ldots\ldots\ldots\ldots [2]$$

which expression may be extended to any number of rises or falls.

(16.)—If the temperature of the workings be considered uniform and equal to θ, the expression [2] becomes

$$= 39{\cdot}74 \left(\frac{D}{459 + T} - \frac{R - F}{459 + \theta} - \frac{d}{459 + t} \right) \ldots\ldots\ldots\ldots [3]$$

in which F is the sum of the vertical height of all dip workings, and R the sum of vertical height of all rise workings; but it is evident that $D + F = d + R \therefore R - F = D - d$, and the expression becomes the same as expression [1]

$$39{\cdot}74 \left(\frac{D}{459 + T} - \frac{D - d}{459 + \theta} - \frac{d}{459 + t} \right)$$

and we consequently arrive at the same conclusion with regard to the increase of the ventilating power under the relative temperatures, as above stated.

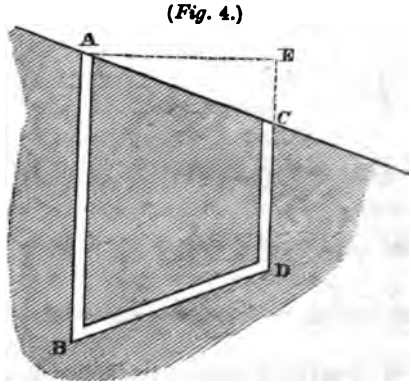
(17.)—It will be remembered that this conclusion is arrived at on the hypothesis that the downcast shaft has decreased in length by the same amount as the upcast has increased. In other words, that with a given depth of shaft, and under the conditions of temperature above stated, *i.e.*, when the average temperature of the upcast is greater than that of the workings, the greatest amount of ventilation accompanies the greatest depth of upcast shaft, and the amount would, consequently, be a maximum were there no downcast shaft, but only gradually descending workings, ventilated by an upcast to the full dip.

It appears also that (subject to the condition of temperature above

named), if we take a case in which the upcast is n fathoms, and the downcast m (m being greater than n), we shall increase the ventilating power by diminishing the depth of the downcast and increasing that of the upcast, and this would go on till at length the upcast was m fathoms and the downcast n, *i.e.*, the positions of the shafts reversed, ***and, consequently, the upcast ought to be placed to the extreme dip of the workings.***

(18.)—In the case when the mouths of the shafts are not on the same horizontal plane the formula above given will still apply, except that we can no longer use D — d in the middle term for the vertical height of the workings, but if we take *(Fig. 4.)* Δ = E C, or the difference of level

(*Fig.* 4.)



of the shafts, and suppose the mouth of the upcast to be below that of the downcast, then instead of D — d in the middle term, we must use

$$D - (d + \Delta)$$

and the expression [1] becomes

$$39{\cdot}74\left(\frac{D}{459 + T} - \frac{D - (d + \Delta)}{459 + \theta} - \frac{d}{459 + t}\right) \ldots\ldots\ldots [4]$$

(19.)—Strictly speaking, the expressions [1], [2], [3], and [4] will not represent the ventilating column, inasmuch as the upcast discharges into a more or less dense atmosphere, compared with the top of the downcast, according as it is situated below or above the level of the same. And if Δ be this difference of level, and be positive, *i.e.*, if the upcast be situated Δ below the downcast, we must diminish the ventilating column by a column equal to Δ at temperature T, but the weight of this column will be $0{\cdot}08657\ \Delta\ \frac{459}{459 + T}$, and introducing this into the expression [4] it becomes

$$39{\cdot}74\left(\frac{D}{459+T}-\frac{D-(d+\Delta)}{459+\theta}-\frac{d}{459+t}-\frac{\Delta}{459+T}\right)$$

$$=39{\cdot}74\left(\frac{D-\Delta}{459+T}-\frac{D-(d+\Delta)}{459+\theta}-\frac{d}{459+t}\right) \quad \ldots\ldots[5]$$

(20.)—This result is on the supposition that the average temperature of the downcast is the same as the external air. If it were not so, but if T_1 were the temperature of the external air, then we should get the ventilating column

$$=39{\cdot}74\left(\frac{D}{459+T}-\frac{\Delta}{459+T_1}-\frac{D-(d+\Delta)}{459+\theta}-\frac{d}{459+t}\right) \ldots[6]$$

$$=39{\cdot}74\left\{D\left(\frac{1}{459+T}-\frac{1}{459+\theta}\right)+\Delta\left(\frac{1}{459+\theta}-\frac{1}{459+T^1}\right)+d\left(\frac{1}{459+\theta}-\frac{1}{459+t}\right)\right\}$$

$$=39{\cdot}74\left\{D\cdot\frac{\theta-T}{(459+T)(459+\theta)}+\Delta\cdot\frac{T^1-\theta}{(459+\theta)(459+T^1)}+d\,\frac{t-\theta}{(459+\theta)(459+t)}\right\}$$

$$=\frac{39{\cdot}74}{459+\theta}\left\{D\frac{\theta-T}{459+T}-\Delta\,\frac{\theta-T^1}{459+T^1}-d\,\frac{\theta-t}{459+t}\right\} \ldots[6\,a]$$

(21.)—It may be observed that the introduction of Δ, that is to say the taking into account the relative levels of the mouths of the shafts, however much it may influence the actual amount of ventilation, does in no way affect the results arrived at in sections (12), (13), and (14), with respect to the variation of the lengths, and the effects thereof on the ventilation, because, if we pay attention to the operations whereby these results were arrived at, we shall find that Δ would disappear in the subtraction, whereby we arrive at the value of the increment or decrement attendant upon a given variation of the shaft, so that we may affirm these conclusions to be true in every case.

(22.)—The expressions [1], [2], [3], [4], [5], and [6], are very convenient, as they avoid any reference of the rise or dip workings to corresponding portions of the shafts, or of each other, and they give directly in lbs. per square foot, the resulting ventilating column of every system of shafts and workings.

(23.)—Let us, for instance, take the example of Backworth Colliery, already referred to, *(see Fig. 1)*, where

Feet.

A B = D = 318 and T = 43°·875
B C = R_1 = 66 .. θ_1 = 53°·125
C F = F_1 = 258 .. T_1 = 58°·5
G F = d = 510 .. t = 77°·5

Then ventilating column, if G F be the upcast,

$$= 39{\cdot}74 \left(\frac{318}{502{\cdot}875} + \frac{258}{517{\cdot}5}\right) + \left(\frac{66}{512{\cdot}125} + \frac{510}{536{\cdot}5}\right) = 2{\cdot}043 \text{ lbs. per sq. ft.}$$

and if A B be the upcast,

$$= 39{\cdot}74 \left(\frac{510}{502{\cdot}875} + \frac{66}{512{\cdot}125} - \frac{258}{517{\cdot}5} + \frac{318}{536{\cdot}5}\right) = 2{\cdot}051$$

therefore we have,

Ventilating column, deep upcast, 2·043 lbs. per square foot.
Ditto, shallow do., 2·051 ditto,

showing, as before, a slight preponderance in favour of the shallow upcast, arising from the cause above explained.

(24.)—It has been already stated (section 7), that in the comparison made in (section 6), we would require a greater furnace power to raise the long upcast to the same mean temperature as the short one, and it is, therefore, proper to examine what proportion such increase of power will assume as compared with the increased effect, which we have seen was about twenty-five per cent.

It is evident that this will depend upon the cooling power of the upcast shaft, which will vary according to circumstances.

(25.)—We now proceed to investigate this question, which resolves itself into finding an equation which shall represent the law of cooling of the air in passing through a shaft or tube of variable temperature, because the temperature of the earth varies according to its depth.

In passing through any small portion, dx of this shaft, at a distance x from the bottom, we will assume,—

1st.—That the loss of temperature is inversely as the quantity of air passing per second.

2nd.—That it is directly as the periphery of the shaft.

3rd.—That it is directly as the difference of temperature between the air and the surface of the shaft at that point.

Let P = the periphery of the shaft.
Q = the quantity of air passing per second.
T = the temperature of the earth at the bottom of the shaft where the air enters.

t = the temperature of the air entering at the bottom.
θ = the temperature lost by the air when it arrives at x.
x = any variable distance from the bottom.
m = co-efficient representing the decrease of temperature of the earth in ascending from the bottom, so that we get,

Temperature of the earth at $x = T - m x$
Ditto air at $x = t - \theta$

consequently, by hypothesis,

Loss of temperature in passing through dx

$$\propto \frac{(t - \theta) - (T - m x)}{V \,.\, A \text{ or } Q} \cdot P$$

$$\text{or } d\,\theta = \frac{a\,P}{Q}\,\overline{(t - \theta - T - m\,x)}\,dx, \text{ (a being a constant)}$$

$$= \frac{a\,P}{Q}\,(t\,dx - \theta\,dx - T\,dx + m\,x\,dx)$$

and integrating on the supposition that θ on the second side is constant.

$$\theta = \frac{a\,P}{Q}\,(t\,x - \theta\,x - T\,x + \frac{m}{2}\,x^2)$$

$$\text{whence } \theta + \frac{a\,P}{Q}\,\theta\,x = \frac{a\,P}{Q}\,(t\,x + \frac{m}{2}\,x^2 - T\,x)$$

$$\text{and } \theta = \frac{a\,P}{Q}\;\frac{\frac{m}{2}\,x^2 + (t - T)\,x}{1 + \frac{a\,P}{Q}\,x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [7]$$

(26.)—It will be observed that in integrating the expression

$$d\,\theta = \frac{a\,P}{Q}\,(t\,dx - \theta\,dx - T\,dx + m\,n\,dx)$$

we have, for the sake of simplicity, considered θ as constant in the second side of the equation, this, however, is evidently incorrect, inasmuch as θ must be a function of x, we shall, therefore, now seek the correct integral, and, for sake of shortness, shall write

$$s \text{ for } t - T$$

$$n \text{ for } \frac{a\,P}{Q}$$

$$\text{then } d\,\theta = -\,n\,\theta\,dx + n\,s\,dx + n\,m\,x\,dx,$$

$$\text{or } d\,\theta + n\,\theta\,dx = n\,s\,dx + n\,m\,x\,dx$$

and multiplying both sides by ϵ^{nx} where ϵ is the base of the Naperian system of logarithms = 2·71828.

$$\epsilon^{nx} d\theta + n\theta\epsilon^{nx} dx = n s \epsilon^{nx} dx + n m x \epsilon^{nx} dx$$

and integrating

$$\theta \epsilon^{nx} = \int n s \epsilon^{nx} dx + \int n m \epsilon^{nx} x \, dx$$

$$\text{now} \int n s \epsilon^{nx} dx = \frac{n s \epsilon^{nx}}{n} = s \epsilon^{nx}$$

$$\text{and} \int n m \epsilon^{nx} x \, dx = n m \left(\frac{x \epsilon^{nx}}{n} - \int \frac{\epsilon^{nx} dx}{n} \right)$$

$$= n m \left(\frac{x \epsilon^{nx}}{n} - \frac{\epsilon^{nx}}{n^2} \right)$$

$$= m x \epsilon^{nx} - \frac{m}{n} \epsilon^{nx}$$

$$\therefore \theta \epsilon^{nx} = s \epsilon^{nx} + m x \epsilon^{nx} - \frac{m}{n} \epsilon^{nx} + C$$

In order to determine C we know that when $x = 0$ $\theta = 0$, therefore

$$0 = s - \frac{m}{n} + C.$$

And subtracting this from the first equation

$$\theta \epsilon^{nx} = s \epsilon^{nx} + m x \epsilon^{nx} - \frac{m}{n} \epsilon^{nx} + \frac{m}{n} - s$$

And dividing by ϵ^{nx}

$$\theta = s + m x - \frac{m}{n} + \frac{m}{n} \epsilon^{-nx} - s \epsilon^{-nx}$$

$$\theta = s + m x - \frac{m}{n} + \left(\frac{m}{n} - s \right) \epsilon^{-nx} \quad \ldots\ldots\ldots\ldots\ldots [8]$$

And substituting for s and n their values

$$\theta = t - T + m x - \frac{m}{\frac{a P}{Q}} + \left(\frac{m}{\frac{a P}{Q}} - t - T \right) \epsilon^{-\frac{a P}{Q} \cdot x} \quad \ldots\ldots\ldots [9]$$

(27.)—We must now seek to deduce the value of n or $\frac{a P}{Q}$ for which purpose let us revert to the equation $\theta = s + m x - \frac{m}{n} + \left(\frac{m}{n} - s \right) \epsilon^{-nx}$ which may be thus written:—

$$\theta = s - \frac{m}{n} + \left(\frac{m}{n} - s \right) \epsilon^{-nx} + m x$$

$$= \left(s - \frac{m}{n} \right) \left(1 - \epsilon^{-nx} \right) + m x$$

$$\theta - s - m\,x = \frac{m}{n}\epsilon^{-nx} - s\,\epsilon^{-nx} - \frac{m}{n} = \alpha$$

(Putting $\theta - s - m\,x = \alpha$)

$$\therefore \left(\frac{m}{n} - s\right)\epsilon^{-nx} = \alpha + \frac{m}{n}$$

$$\text{whence } \log.\left(\frac{m}{n} - s\right) - n\,x = \log.\left(\alpha + \frac{m}{n}\right)$$

$$\text{Log.}\left(\frac{\frac{m}{n} - s}{\alpha + \frac{m}{n}}\right) = n\,x = \log.\frac{m - s\,n}{n\,\alpha + m}$$

(28).—If we neglect the variation of the temperature of the earth, which we may do without much error, we have only to make $m = 0$ in the equation [8], which then becomes

$$\theta = t - T + (-(t - T))\,\epsilon^{-nx}$$

$$= (t - T)\left(1 - \frac{1}{\epsilon^{nx}}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots [8\,a]$$

Also, the equation in section (28) for the value of n or

$$n\,x = \log.\epsilon\frac{m - s\,n}{n\,\alpha + m}$$

becomes $n\,x = \log.\epsilon\frac{-s}{\alpha}$ and substituting for s its value $t - T$, and for α its value $\theta - s - m\,x$, which becomes $\theta - s$ or $\theta - (t - T)$ we get

$$n\,x = \log.\epsilon\frac{-(t - T)}{\theta - (t - T)} = \log.\epsilon\frac{T - t}{T - t + \theta}$$

$$\text{or } n = \frac{\log.\epsilon\left(\frac{T - t}{T - t + \theta}\right)}{x}$$

$$n = \frac{2{\cdot}3\,\log._{\cdot 10}\left(\frac{T - t}{T - t + \theta}\right)}{x} \quad \ldots\ldots\ldots\ldots\ldots [8\,b]$$

These equations are much simpler than the more correct ones, and may practically be used without error, but at present we will make use of the first expressions, which we now proceed to apply to practice, taking the data from the 1st column of the table at page 178 of Mr. Greenwell's work on "Mine Engineering."

(29.)—The equation $n\,x = \log. \frac{m - s\,n}{n\,\alpha + m}$ can only be solved approximately, which we shall now do.

We have

$x = 65$ fathoms

$\theta = 138 - 91 = 47°$

$T = 56°{\cdot}5$, as given at page 90 of Mr. Greenwell's work, for a depth of 65 fathoms

$t = 138°$

$m = \frac{6}{41{\cdot}1} = 0{\cdot}146$ per fathom, being at the rate of 1° for 41·1 feet

$s = t - T = 81{\cdot}5$

then $\alpha = \theta - (t - T) - m\,x$

$= 47 - 81{\cdot}5 - 0{\cdot}146 \times 65 = -44$

and $65\,n = \log. \frac{0{\cdot}146 - 81{\cdot}5\,n}{0{\cdot}146 + (n \times -44)} = \log. \frac{81{\cdot}5\,n - 0{\cdot}146}{44\,n - 0{\cdot}146}$

and, as these are the Naperian logarithms, we will divide by 2·3 which will give the common logs., or

$$28{\cdot}26\,n = \log._{10} \frac{81{\cdot}5\,n - 0{\cdot}146}{44\,n - 0{\cdot}146}$$

as a first approximation let us suppose

$n = {\cdot}01$

then $= 0{\cdot}2826 - \log. \frac{{\cdot}669}{{\cdot}294} = 0{\cdot}2826 - {\cdot}3571 = -0{\cdot}0745$

$n = {\cdot}02$

then $0{\cdot}5652 - \log. \frac{1{\cdot}484}{734} = 0{\cdot}5622 - {\cdot}3057 = +\,0{\cdot}2595$

$0{\cdot}3340$

As $0{\cdot}3340 : 0{\cdot}01 :: {\cdot}0745 : {\cdot}00223$

$\therefore$ Try $n = 0{\cdot}01223$

$0{\cdot}34492 - \log. \frac{{\cdot}8507}{{\cdot}3921} = 0{\cdot}34492 - {\cdot}33638 = \ldots\ldots + {\cdot}00854$

and taking again from $n = {\cdot}01 \ldots\ldots\ldots\ldots\ldots\ldots - {\cdot}07450$

${\cdot}08304$

${\cdot}08304 : {\cdot}00223 :: {\cdot}00854 : {\cdot}00023$

Try $n = 0{\cdot}01246$

then $0{\cdot}3521 - \log. \frac{{\cdot}867}{402} = 0{\cdot}3521 - {\cdot}3379 = \ldots\ldots\ldots\ldots {\cdot}0142$

$n = {\cdot}012$

${\cdot}33912 - \log. \frac{832}{382} - {\cdot}33912 - 33806 = \ldots\ldots\ldots\ldots + {\cdot}00106$

(30.)—This value of n being taken as sufficiently near, let us now seek the value of θ from the equation $\theta = s + m x - \frac{m}{n} + \left(\frac{m}{n} - s\right) e^{-n s}$

Where $s = t - T = 81{\cdot}5$

$m = 0{\cdot}146$

$n = 0{\cdot}012$

$e = 2{\cdot}71828$

Let $x = 50$

$\theta = 81{\cdot}5 + 7{\cdot}3 - 12{\cdot}17 + (12{\cdot}17 - 81{\cdot}5)\ 2{\cdot}718^{-\cdot 6}$

$= 76{\cdot}63 + -\frac{69{\cdot}33}{1{\cdot}822} = 76{\cdot}63 - 38 = 38{\cdot}63$

$\therefore$ temperature at 50 fathoms from bottom

or at 15 fathoms from top $= 138 - 38{\cdot}63$

$= 99{\cdot}37$

the observed temperature being 93·5

Next let $x = 10$, then $\theta = 9°{\cdot}30$

$x = 20$ ..... $\theta = 17°{\cdot}75$

$x = 30$ ..... $\theta = 25°{\cdot}34$

$x = 40$ ..... $\theta = 32°{\cdot}27$

$x = 60$ ..... $\theta = 44°{\cdot}34$

$x = 70$ ..... $\theta = 49°{\cdot}62$

(31.)—Tabulating these values and comparing them with the observed values as given by Mr. Greenwell, we get

x	θ	$t - \theta$	Observed Value.	Difference.
10 ..	9·3 ..	128·7 ..	110 ..	18·7
20 ..	17·75 ..	120·25 ..	105 ..	15·25
30 ..	25·34 ..	112·66 ..	105 ..	7·66
40 ..	32·27 ..	105·73 ..	97 ..	8·73
50 ..	38·63 ..	99·37 ..	93·5 ..	5·87
60 ..	44·34 ..	93·66 ..	91·5 ..	2·16
70 ..	49·62 ..	88·38		

(32.)—Reverting to the first expression for θ.....[7]

$$\theta = \frac{a P}{Q} \cdot \frac{\frac{m}{2} x^2 + (t - T) x}{1 + \frac{a P}{Q} x}$$

and taking the same data as in Section (29) we get

$$47 = \frac{a P}{Q} \cdot \frac{\cdot 073 \times 65^2 + 81{\cdot}5 \times 65}{1 + \frac{a P}{Q} \times 65}$$

$$\therefore 47 + \frac{a\,P}{Q} \times 65 \times 47 - \frac{a\,P}{Q} \cdot (\cdot073 \times 65^3 + 81\cdot5 \times 65) = 0$$

$$\text{Whence } \frac{a\,P}{Q} = \cdot01842$$

and substituting this value in [7]

$$\theta = \cdot01842 \left(\frac{\cdot073\,x^2 + 81\cdot5\,x}{1 + \cdot01842\,x} \right)$$

$x = 10$

$$\theta = \cdot01842 \left(\frac{7\cdot3 + 81\cdot5}{1\cdot1842} \right) = 12°\cdot8 \therefore (t - \theta) = 125\cdot2$$

$x = 20$

$$\theta = \cdot01842 \left(\frac{28\cdot6 + 1630}{1\cdot3684} \right) = 22°\cdot3 \therefore \quad " \quad = 115\cdot7$$

$x = 30$

$$\theta = \cdot01842 \left(\frac{65\cdot7 + 2445}{1\cdot5522} \right) = 29°\cdot8 \therefore \quad " \quad = 108\cdot2$$

$x = 40$

$$\theta = \cdot01842 \left(\frac{114\cdot4 + 3260}{1\cdot7368} \right) = 35°\cdot8 \therefore \quad " \quad = 102\cdot2$$

$x = 50$

$$\theta = \cdot01842 \left(\frac{182\cdot5 + 4075}{1\cdot9210} \right) = 40°\cdot8 \therefore \quad " \quad = 97\cdot2$$

$x = 60$

$$\theta = \cdot01842 \left(\frac{262\cdot8 + 4890}{2\cdot1044} \right) = 45°\cdot1 \therefore \quad " \quad = 92\cdot2$$

$x = 70$

$$\theta = \cdot01842 \left(\frac{357\cdot7 + 5705}{2\cdot2894} \right) = 48°\cdot79 \therefore \quad " \quad = 89\cdot21$$

In order to compare these results with those given by equation [9], as well as with those actually observed, I have laid them down in the form of curves. The irregular form of the curve of observed temperatures is due to the difficulties of observation; and the following diagrams show the relative positions and significations of the curves.

Actual observations marked thus ———————

Formula [11] ..... - - - - - - - - - -

Formula [9] ....o.....o.....o.....o

Formula [7] ....•.....•.....•.....•

A reference to these diagrams will show that the loss of temperature

proceeds much more rapidly than is indicated by either of the above formulæ, but is very nearly represented by an empirical formula [11], which we shall soon investigate.

(34.)—This result is probably due to the effect of water or moisture in the shaft, and as the subject is one of great importance we shall inquire a little further into it, so as to find out what amount of loss is actually due to causes which, being independent of what we may call the natural law of cooling, may, therefore, to some extent be under our control.

(35.)—What we have termed the natural law of cooling is very nearly represented by the formula [9].

It should, however, be observed that this is based upon the hypothesis that the velocity of cooling is proportional to the difference of temperature of the body cooled, and the cooling medium, or $V \propto t - t^1$. But, as is well known, this hypothesis, though nearly correct for moderate differences of temperature, varies from the truth in great differences, in which case the rate of cooling is more accurately determined by the law of Dulong and Petit, viz. :—

$$V = m\,(a^{t-t^1} - 1) + n\,(t - t^1)^b$$

When $a = 1{\cdot}0077$ and $b = 1{\cdot}233$ and m and n are co-efficients depending on the nature of the cooling body and medium.

As, however, the introduction of this expression would greatly complicate the result, without seriously altering it *within the range of temperatures with which we have here to deal*, we think it best to make use of the more simple hypothesis, that the loss of heat is simply as the difference of temperature.

There is, however, another circumstance which, in order to be strictly accurate, ought to be taken into account.

The loss of temperature in passing through any small portion of the shaft being inversely as the velocity of the air at that point, and the velocity being as the volume, and the volume again being a function of the temperature, it is evident that the velocity decreases as the air ascends, and consequently the cooling will be less rapid at first and more so afterwards, *or* the true curves will be flatter or less concave than those given by the above equation, or the loss of temperature more nearly uniform.

This should be borne in mind when we come to compare the average loss as represented by our formula with the average loss as determined by the empirical formula which we shall afterwards determine to represent

the curve of actual observation, because the effect will be that our results will be diminished and not exaggerated by this neglect of strict accuracy.

If we wish to take into account this variation of the velocity, we must revert again to the equation $d\,.\,\theta = \frac{a\,P}{Q}\,(t - \theta - \overline{T - m\,x})\,dx$, and putting V A for Q where V = velocity of air at x, and A = area of shaft

$$d\,\theta = \frac{a\,.\,P}{A}\left(\frac{t - \theta - \overline{T - m\,x}}{V}\right) dx$$

but if V^1 be the velocity of the air at the bottom

$$V : V^1 :: \text{vol. of air at } x : \text{vol. at bottom}$$

$$\text{but vol. at } x : \text{vol. at bottom} :: 459 + (t - \theta) : 459 + t$$

$$\text{or } V : V^1 :: 459 + t - \theta : 459 + t$$

$$\therefore V = V^1\,\frac{459 + t - \theta}{459 + t} = V^1\left(1 - \frac{\theta}{459 + t}\right)$$

$$\therefore d\,\theta = \frac{a\,P}{A\,V^1}\left(\frac{t - \theta - \overline{T - m\,x}}{1 - \dfrac{\theta}{459 + t}}\right) d\,x$$

and putting as before $\frac{a\,P}{A\,V^1} = \frac{a\,P}{Q} = n$

$$t - T = s$$

$$\frac{1}{459 + t} = b$$

$$d\,\theta = n\left(\frac{s - \theta + m\,x}{1 - b\,\theta}\right) dx \quad .$$

or $d\,\theta - b\,\theta\,d\,\theta = n\,s\,dx + n\,m\,x\,dx - n\,\theta\,dx$

$d\,\theta - b\,\theta\,d\,\theta + n\,\theta\,dx = n\,s\,dx + n\,m\,x\,dx$

by integrating which expression we should find the true value of θ.

This is, however, perhaps unnecessary, as it would lead to a very complicated expression without making any material difference in the result.* And as any error arising from considering the velocity constant only reduces the difference which we shall hereafter point out between the case as given by our formula and the actual observation, we may safely depend upon our deductions as being below the reality rather than exaggerations thereof.

* The integration of this expression, for which I am indebted to my friend Mr. C. H. Brooks, of Newcastle-upon-Tyne, is given at the end of the paper.

In other words, if we can show from the actually observed result as compared with that due to the law of cooling, as embodied in formula [9], a loss arising from causes within our control, we may be certain that such loss is actually greater than it appears, in consequence of our having considered V constant in the investigation which led us to [9].

(36.)—Having the equation [9], we can easily find therefrom the actual value of t in a given shaft, so as to obtain any proposed average temperature in that shaft.

If we could also express the curve of actual observation accurately by an equation, we could then also in that case determine the initial value of t requisite to give the same average temperature in the shaft; and by comparing these values of t we shall have an accurate account of the relative furnace power in the two cases, and consequently of the amount of furnace power actually wasted by those causes over which we have more or less control.

We shall, therefore, seek an empirical equation representing the curve of actual observation.

(37.)—We observe that the curve of formula [7] approaches more nearly to the curve of actual observation than that of formula [9], and we shall, therefore, assume an equation of that form, and seek to determine the coefficient of the power of x from the results of experiment. Therefore, let

$$A = \frac{a\,P\,m}{Q\,2}$$

$$B = \frac{a\,P}{Q}\,(t - T)$$

$$C = \frac{a\,P}{Q}$$

$$\text{or } \theta = \frac{A\,x^2 + B\,x}{1 + C\,x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [10]$$

and taking the following values from the curve of observation

x	θ°
5	15
10	23
30	37
65	47

we get when $x = 5$

$$15 = \frac{25\,A + 5\,B}{1 + 5\,C} \quad \therefore \; 15 + 75\,C = 25\,A + 5\,B$$

$$\therefore \; 30 + 150\,C = 50\,A + 10\,B$$

when $x = 10$

$$23 = \frac{100\,A + 10\,B}{1 + 10\,C} \quad \therefore\ 23 + 230\,C = 100\,A + 10\,B$$

and subtracting $\quad -7 + 80\,C = 50\,A \ldots\ldots\ldots (\alpha)$

again

when $x = 30$

$$37 = \frac{900\,A + 30\,B}{1 + 30\,C} \quad \therefore\ 37 + 1110\,C = 900\,A + 30\,B$$
$$\therefore\ 80{\cdot}16 + 2405\,C = 1950\,A + 65\,B$$

and when $x = 65$

$$47 = \frac{4225\,A + 65\,B}{1 + 65\,C} \quad \therefore\ 47 + 3055\,C = 4225\,A + 65\,B$$

and subtracting $\quad -33{\cdot}16 + 650\,C = 2275\,A \ldots\ldots\ldots (\beta)$

but from (α) $\quad -318{\cdot}50 + 3640\,C = 2275\,A$

therefore $\quad -285{\cdot}34 + 2990\,C = 0$

$$C = \frac{285{\cdot}34}{2990} = 0{\cdot}09544$$

therefore, from (α)

$$50\,A = (0{\cdot}09544 \times 80) - 7$$

whence $A = 0{\cdot}012704$

and from our first equation

$$B = 3 + 15\,C - 5\,A$$
$$= 3 + 15 \times 0{\cdot}09544 - 5 \times 0{\cdot}012704$$
$$= 4{\cdot}3731$$

therefore, substituting these values in equation [10]

we get $\theta = \dfrac{0{\cdot}012704\,x^2 + 4{\cdot}3731\,x}{1 + 0{\cdot}09544\,x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [11]$

from which we may calculate the following series of values:

x	θ	$t - \theta$	Observed Values of $(t - \theta)$
10	23·03	114·97	110
20	31·80	106·20	105
30	36·92	101·08	105
40	40·5	97·50	97
50	43·4	94·60	93·5
60	45·8	92·20	91·5
70	47·96	90·04	

which values correspond very exactly with the curve of observation, as will be seen by referring to the diagram, and to the following table representing the value of $t - \theta$ as deduced from the respective formula and as actually observed.

Values of $t - \theta$

x	Formula [8]	Formula [7]	Form. [11]	Observed.
10	128°·7	125°·2	114°·97	110°
20	120°·25	115°·7	106°·20	105°
30	112°·66	108°·2	101°·08	105°
40	105°·73	102°·2	97°·50	97°
50	99°·34	97°·2	94°·60	93°·50
60	91°·5	92°·2	92°·20	91°·50

(38.)—Having now got the two equations [11] and [8], the former representing the actually observed loss of temperature, and the other the loss which would take place under the natural law of cooling, we proceed to show how to obtain an expression for the mean loss of temperature of the shaft corresponding to any given initial temperature, or *vice versa*.

It is evident that this may be done by taking the area of the curve, which represents the loss, and dividing it by the length of the shaft. Now, the general expression for the area of a curve is $\int y\, dx$.

In this case $y = \theta$ and the equations [8] and [11] give the relation between θ and x, therefore from [8]

$$\text{area} = \int \theta\, dx = \int \left\{ s + m x - \frac{m}{n} + \left(\frac{m}{n} - s\right) \epsilon^{-nx} \right\} dx$$

$$= \int s\, dx + \int m x\, dx - \int \frac{m}{n}\, dx + \int \left(\frac{m}{n} - s\right) \epsilon^{-nx}\, dx$$

$$= s x + \frac{m}{2} x^2 - \frac{m}{n} x - \left(\frac{m}{n^2} - \frac{s}{n}\right) \epsilon^{-nx} + C$$

but when $x = 0$ $\int \theta\, dx = 0$

$$\therefore 0 = -\left(\frac{m}{n^2} - \frac{s}{n}\right) + C$$

and subtracting

$$\int \theta\, dx = s x + \frac{m}{2} x^2 - \frac{m}{n} x - \left(\frac{m}{n^2} - \frac{s}{n}\right) \epsilon^{-nx} + \frac{m}{n^2} - \frac{s}{n} \quad \ldots [12]$$

$$\therefore \int \frac{\theta\, dx}{x} = s + \frac{m}{2}x - \frac{m}{n} + \frac{1 - e^{-nx}}{x} \cdot \left(\frac{m}{n^2} - \frac{s}{n}\right) \ldots\ldots [13]$$

which is the mean loss throughout the length x, and if x become d the depth of the upcast

$$\text{Mean loss} = s + \frac{m}{2}d - \frac{m}{n} + \left\{\frac{1 - e^{-nd}}{d}\right\}\left(\frac{m}{n^2} - \frac{s}{n}\right) \ldots\ldots [14]$$

(39.)—Proceeding in like manner with the equation [10] we get

$$\text{area} = \int \theta\, dx = \int \left(\frac{A x^2 + B x}{1 + C x}\right) dx$$

$$= \int \frac{A x^2\, dx}{1 + C x} + \int \frac{B x\, dx}{1 + C x}$$

$$= A\left\{\frac{x^2}{2C} - \frac{x}{C^2} + \frac{1}{C^3}\text{Log.}(1 + C x)\right\} + B\left\{\frac{x}{C} - \frac{1}{C^2}\text{Log.}(1 + C x)\right\} + C^1$$

but when $x = 0$ this expression becomes $0 = C^1$

$$\therefore \int \theta\, dx = A\left\{\frac{x^2}{2C} - \frac{x}{C^2} + \frac{1}{C^3}\text{Log.}(1 + C x)\right\} + B\left\{\frac{x}{C} - \frac{1}{C^2}\text{Log.}(1 + C x)\right\}$$

$$\text{and} \int \frac{\theta\, dx}{x} = A\left\{\frac{x}{2C} - \frac{1}{C^2} + \frac{1}{C^3}\frac{\text{Log.}(1 + C x)}{x}\right\} + B\left\{\frac{1}{C} - \frac{1}{C^2}\frac{\text{Log.}\, 1 + C x}{x}\right\}$$

and when $x = d$

$$\text{Mean loss} = A\left(\frac{d}{2C} - \frac{1}{C^2} + \frac{1}{C^3}\frac{\text{Log.}\, 1 + C d}{d}\right) + B\left(\frac{1}{C} - \frac{1}{C^2}\frac{\text{Log.}(1 + C d)}{d}\right) [15]$$

(40.)—If now we substitute in these expressions, [14] and [15], the numerical values obtained in section (30) and section (37),

we shall get, making $d = 65$

from [14]

$$\text{Mean loss} = 81{\cdot}5 + 0{\cdot}073 \times 65 - \frac{0{\cdot}146}{0{\cdot}012} + \left(\frac{1 - 2{\cdot}718^{-0{\cdot}012 \times 65}}{65}\right)\left(\frac{0{\cdot}146}{0{\cdot}012^2} - \frac{81{\cdot}5}{0{\cdot}012}\right)$$

$$= 81{\cdot}5 + 4{\cdot}745 - 12{\cdot}16 + \left(\frac{{\cdot}5404}{65} \times -5777\right)$$

$$= 81{\cdot}5 + 4{\cdot}745 - 12{\cdot}16 - 48{\cdot}93$$

$$= 26^{\circ}{\cdot}055$$

and from (15)

$$\text{Mean loss} = 0{\cdot}012704\left(\frac{65}{{\cdot}19088} - \frac{1}{|0{\cdot}09544|^2} + \frac{1}{|0{\cdot}09544|^3} \times \frac{\text{Log.}_e(1 + 0{\cdot}09544 \times 65)}{65}\right)$$

* The logarithms are, of course, the Naperian logarithms, and may be found by multiplying the common logarithms by 2·30259.

$$+ 4{\cdot}3731 \left(\frac{1}{{\cdot}09544} - \frac{1}{0{\cdot}09544\,|^2} \times \frac{\text{Log.}_\epsilon\,(1 + 0{\cdot}09544 \times 65)}{65} \right)$$

$$= 0{\cdot}012704 \left(340{\cdot}5 - 109{\cdot}7 + 1150{\cdot}4 \times \frac{\text{Log.}_\epsilon\,7{\cdot}205}{65} \right)$$

$$+ 4{\cdot}3731 \left(10{\cdot}48 - 109{\cdot}7 \times \frac{\text{Log.}_\epsilon\,7{\cdot}205}{65} \right)$$

$$= 0{\cdot}012704\,(230{\cdot}8 + 34{\cdot}09) + 4{\cdot}3731\,(10{\cdot}48 - 3{\cdot}33)$$

$$= 3{\cdot}365 + 31{\cdot}27 = 34°{\cdot}635$$

Now, in each case, the initial temperature was 138°, therefore the mean temperatures would be

$$\left.\begin{array}{ll} 138 - 26 & = 112° \\ 138 - 34{\cdot}6 & 103°{\cdot}4 \end{array}\right\} \text{respectively,}$$

making a difference of 8°·6.

And taking the respective weights of the columns from the expression $0{\cdot}08657\ D \frac{459}{459 + t}$ when D = depth in feet we get

Weight of column at 103°·4 = 34·70 lbs. per square foot.

Do. at 112° 34·12 „

·58 „

being a difference of 0·58 lbs. per square foot.

(41.)—Although this shews a considerable difference in favour of the natural law of cooling, it must not be taken as representing the whole result which may be gained by preventing the cooling action of water, &c., in the shaft, for the following reasons:—

In calculating the value of the constant n or $\frac{a\ P}{Q}$ of equation [8] and [9], we found it from taking $\theta = 138° - 91°$ or the total loss of temperature, as recorded, by Mr. Greenwell, in an experiment at Marley Hill colliery; but it must be recollected that this is the value of θ in a shaft which is evidently in a very bad condition as regards cooling power. If, means were adopted to prevent this excessive cooling action, or if an experiment were tried in a perfectly dry shaft, we should obtain a much lower value for n, which would, of course, to a corresponding extent, diminish the values of θ, and consequently the mean loss.

The result which is given above, only shews the comparative effect of two cases in the same shaft, when the final temperature at the exit is the same in both; and the difference arises from the cooling in the one case taking place more rapidly than in the other.

(42.)—So great a loss of temperature as we have shewn to exist, viz., an average loss of 34°·6, out of an initial temperature of 138°, demands the most serious attention. If we suppose the air from the returns to have reached the furnace at 65°, the heat imparted by the furnace will be 138° — 65 = 73°, of which we lose, by the cooling action of the shaft, 34°·6, or nearly one half.

Looking at it as affecting the weight of the upcast column, the result will be as

$$0{\cdot}08657\ D\frac{459}{459+138} : 0{\cdot}08657\ D\frac{459}{459+103} :: \overset{\text{lbs.}}{32{\cdot}66} : \overset{\text{lbs.}}{34{\cdot}70}$$

or a difference of more than 2lbs. per square foot. If we suppose the temperature of the downcast to have been 51°, the weight of its column would be 38·23 lbs. per square foot; so that we arrive at this result, viz., that, whereas in actual practice, the ventilating column was equal to 38·23 — 34·70 = 3·53lbs. per square foot; yet, if we could have prevented the cooling in the upcast, the same furnace power would, if the same quantity of air were passing, have given us 38·23 — 32·66 = 5·57lbs. per square foot; in other words the cooling in the shaft costs us 36½ per cent. of the furnace power.

If we investigate an empirical equation for the observations given in the last column of Mr. Greenwell's table, we shall get, proceeding as in section (37),

$$\theta = \frac{0{\cdot}077\,x^2 + 9{\cdot}15\,x}{1 + 0{\cdot}155\,x}$$

from which we may deduce the following values—

x	θ	$t - \theta$	Observed Temperature.
1	7°·989	171·5	"
10	38°·900	141·5	140·5
20	52°·100	129·5	130·0
30	60°·900	119·5	125·0
40	68°·000	112·5	108·0
50	74°·300	106·2	102·5
60	80°·000	100·5	103·

and the mean loss as deduced from formula [15] will be found to be 58°·64.

Now, in this case the initial temperature was 180½°, and supposing, as before, that the air reached the furnace at 65°, the heat given out by the furnace would be 180·5 — 65 = 115°·5, of which there is lost by cooling of the shaft 58°·64, or about 51 per cent.

(43.)—In order to render the above equation practically useful, it is very desirable that observations should be made on shafts perfectly free from water and other causes tending to lower the temperature beyond that due to the conducting power of the earth, as well as in shafts lined with different materials so as to diminish this conducting power.

The observations would be easily made, as we only require the temperatures at the bottom and top of the shafts.

(44.)—We now proceed to find an expression for the initial temperature requisite to give any required average temperature in the shaft, calling T this average temperature we have initial temperature =

average temperature + average loss,

$$\text{or } t = T + \int \frac{\theta \, dx}{x} \text{ when } x = d \text{ the depth}$$

of the shaft or from equation [14]

$$t = T + S + \frac{m}{2} \cdot d - \frac{m}{n} + \left(\frac{1 - e^{-nd}}{d}\right)\left(\frac{m}{n^2} - \frac{S}{n}\right)$$

and putting for S its value $t - T$

$$t = T + t - T + \frac{m}{2} d - \frac{m}{n} + \left(\frac{1 - e^{-nd}}{d}\right)\frac{m}{n^2} - \left(\frac{1 - e^{-nd}}{d}\right)\left(\frac{t - T}{n}\right)$$

$$\therefore 0 = T - T + \frac{m}{2} d - \frac{m}{n} + \left(\frac{1-e^{-nd}}{d} \cdot \frac{m}{n^2}\right) - \left(\frac{1-e^{-nd}}{d} \cdot \frac{t}{n}\right) + \frac{1-e^{-nd}}{d} \cdot \frac{T}{n}$$

therefore

$$t = \frac{T - T + \frac{m}{2} d - \frac{m}{n} + \left(\frac{1 - e^{-nd}}{d}\right)\left(\frac{m}{n^2} + \frac{T}{n}\right)}{\frac{1 - e^{-nd}}{d\,n}}$$

$$= \frac{d\,n\,(T - T) + \frac{m\,n}{2} d^2 - m\,d + (1 - e^{-nd})\left(\frac{m}{n} + T\right)}{1 - e^{-nd}} \quad \ldots [16]$$

$$= \frac{(n\,(T - T) - m)\,d + \frac{m\,n}{2} \cdot d^2 + (1 - e^{-nd})\left(\frac{m}{n} + T\right)}{1 - e^{-nd}}$$

From expression [15] we may also deduce a value of t as follows—

$$t = T + A\left(\frac{d}{2C} - \frac{1}{C^2} + \frac{1}{C^2} \times \frac{\text{Log.}1 + Cd}{d}\right) + B\left(\frac{1}{C} - \frac{1}{C^2}\frac{\text{Log.}1 + Cd}{d}\right)$$

$$\text{but } B = \frac{a\,P}{Q}(t - T) \;\&\; C = \frac{a\,P}{Q}$$

$$\therefore B = C(t - T)$$

$$\text{and } t = T + A(\&c.) + (t - T)\left(1 - \frac{1}{C} \cdot \frac{\text{Log. } 1 + C d}{d}\right)$$

$$\therefore t - t\left(1 - \frac{\text{Log.}(1+Cd)}{C.d}\right) = T + A\left(\frac{d}{2C} - \frac{1}{C^2} + \frac{\text{Log.}1+Cd}{C^2 d}\right) - T\left(1 - \frac{\text{Log.}1+Cd}{C.d}\right)$$

$$t = \frac{T + A\left(\frac{d}{2C} - \frac{1}{C^2} + \frac{\text{Log.}(1+Cd)}{C^2 d}\right) - T\left(1 - \frac{\text{Log.}(1+Cd)}{Cd}\right)}{\frac{\text{Log.}(1+Cd)}{Cd}}$$

$$= \frac{Cd\,T + A\left(\frac{d^2}{2} - \frac{d}{C} + \frac{\text{Log.}(1+Cd)}{C^2}\right) - T(Cd - \text{Log.}(1+Cd))}{\text{Log.}(1+Cd)}$$

$$= \frac{Cd(T-T) + A\left(\frac{d^2}{2} - \frac{d}{C} + \frac{\text{Log.}(1+Cd)}{C^2}\right) + T\,\text{Log.}(1+Cd)}{\text{Log.}(1+Cd)}$$

$$= \frac{Cd(T-T) + A\left(\frac{d^2}{2} - \frac{d}{C}\right)}{\text{Log.}(1+Cd)} + \frac{A}{C^2} + T. \quad \ldots\ldots\ldots\ldots [17]$$

(45.)—Having thus obtained an expression giving the initial temperature required to produce a given average temperature in the shaft, we are now in a position to return to the question which presented itself under section (25), which was to determine the relative furnace powers required to give the same average temperatures of 110° in the two upcasts referred to in section (8).

In the absence of positive data as to the actual loss of heat in this shaft, from which to deduce the correct value of the constants, we will assume the shaft to have been in the same condition as regards its cooling power, as that of Marley Hill, given by Mr. Greenwell, from which we have calculated the constants in sections (29) and (37).

And taking equation [16], we get,

When A B is the upcast,

$$t = \frac{53 \times 0{\cdot}012(110 - 56{\cdot}5) + \frac{0{\cdot}146 \times 0{\cdot}012}{2} \times 53^2 - 0{\cdot}146 \times 53 + (1 - 2{\cdot}718^{-{\cdot}012 \times 53}) \times \left(\frac{0{\cdot}146}{0{\cdot}012} + 56{\cdot}5\right)}{1 - 2{\cdot}718^{-{\cdot}012 \times 53}}$$

$$= \frac{68{\cdot}696}{0{\cdot}4705} = 146°$$

Again, when G F is the upcast

$$t = 85 \times 0{\cdot}012(110 - 56{\cdot}5) + \frac{0{\cdot}146 \times 0{\cdot}012}{2} \times 83^2 - 0{\cdot}146 \times 85 + (1 - 2{\cdot}718^{-{\cdot}012 \times 53}) \times \left(\frac{0{\cdot}146}{0{\cdot}012} + 65{\cdot}5\right)$$

$$= 154°{\cdot}5$$

(46.)—From this it appears that the respective temperatures, when entering the upcast shaft, would require to have been 146° and 154½°, but the temperature at the end of the dip workings was 58°·5, consequently the additional temperature to be imparted by the furnace would be

Short upcast 146 — 58·5 = 87·5

Long upcast 154·5 — 58·5 = 96·

or an increase of about ten per cent. But it was shown that the increase of ventilating column, under these circumstances, was twenty-five per cent., therefore, it appears that by an increase of furnace power of ten per cent., we gain an increase of ventilating column of twenty-five per cent., and, consequently, even allowing for the cooling of the upper part of the shaft, there is still a considerable gain in the direct upcast.

(47.)—Practically the gain would be greater than we have arrived at, because the cooling in the shaft proceeds more rapidly than is indicated by equation [8], from whence equation [16] is derived.

(48.)—In conclusion we must again direct attention to the serious loss of temperature in upcast shafts, and the means which may be tried to prevent it, and for that purpose shall now endeavour to deduce an expression for the cooling power of a shaft which shall not be dependent upon any of the data above referred to, but being based upon the law of cooling, and the ascertained conducting power of bodies shall enable us to determine *a priori* the amount of heat which would be lost in a shaft properly protected from water by lining of various materials. We shall then be in a position to ascertain the respective value of such measures as a means of retaining the heat of the upcast air.

For this purpose let us take as before

T = temperature of the earth at bottom of upcast.

t = ditto air ditto.

θ = ditto ditto at x.

x = any variable distance from bottom of upcast in fathoms.

m = co-efficient for decrease of temperature of earth in ascending, so that temperature at x = T — m x.

Q = Cubic feet of air passing per second into the upcast at temperature *T*.

$$W = \text{weight of } Q = 0{\cdot}08657\ Q\ \frac{459}{459 + T}$$

0·2669 = specific heat of air, that of water being = 1

therefore, unities of heat in W at temperature t

$$= {\cdot}2669\ Wt$$

which is the quantity of heat passing into the upcast per second.

Now d θ is the loss of temperature in passing through dx, therefore unities of heat lost in passing dx

$= \cdot 2669\ W\ d\ \theta$, which must of course be equal to the heat transmitted through the same space.

Then the heat passing through 1 square foot of surface in 1″ $= \frac{K\ C}{3600\ (K\ e + C)}\ (t^1)$ where K and C are constants depending upon the conducting and transmitting power of the material of which the lining is composed, and e is the thickness in feet of the lining, and t^1 the difference of temperature.

Consequently the heat passing through 1 square fathom

$$= \frac{K\ C}{100\ (K\ e + C)}\ t^1. \text{ but } t^1 = (t - \theta) - (T - mx)$$

$\therefore$ heat lost in passing through the space dx, of which the surface is P. dx (P being the periphery of the shaft also in fathoms), will be

$$\frac{K\ C}{100\ (K\ e + C)} \cdot \overline{(t - \theta - \overline{T - mx})}\ P\ dx$$

$$\therefore \cdot 2669\ W\ d\ \theta = \frac{K\ C}{100\ (K\ e + C)} \cdot P.\ (t - \theta - T + m\ x)\ dx$$

$$\therefore d\ \theta = \frac{K\ C\ P}{\cdot 2669 \times 100 \times W\ (K\ e + C)} \cdot (t - \theta - T + m\ x)\ dx$$

and writing $n = \frac{K\ C\ P}{26{\cdot}69\ W\ (K\ e + C)}$

$$d\ \theta = n\ (t - \theta - T + mx)\ dx$$

$$= n\ t\ dx - n\ \theta\ dx - n\ T\ dx + n\ m\ x\ dx$$

and making $t - T = s$

$$d\ \theta + n\ \theta\ dx = n\ s\ dx + n\ m\ x\ dx$$

which is the same expression which we had before section (1) and integrating as in that place $\theta = S + m\ x - \frac{m}{n} + \left(\frac{m}{n} - S\right) e^{-nx}$

or putting for S and n their values

$$\theta = (t - T) + mx - \frac{m.26{\cdot}69\ W.\ (K\ e + C)}{K\ C\ P} + \left\{\frac{m.26{\cdot}69\ W\ (K\ e + C)}{K\ C\ P} - (t - T)\right\} e^{-\frac{K\ C\ P.\ x}{26{\cdot}69\ W\ (K\ e + C)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [18]$$

If we suppose $m = 0$, or that the temperature of the earth does not vary in ascending, which may probably approach the truth in wet shafts, we will have

$$y = t - T - \overline{t - T}\, e^{-\frac{K C P x}{95{\cdot}03\, W (K e + C)}} = t - T\left(1 - \frac{1}{e^{\frac{K C P x}{95{\cdot}03\, W (K e + C)}}}\right) \quad [19]$$

)—The expression $\frac{K C}{100 K e + C} t^1$ for the quantity of heat passing

ou hickness of wall, is that given by Péclet in his "Traité
Chale and the following table gives the values of K and C, which
esent the following constants :—

= Coefficient of transmission or quantity of unities of heat passing in 1 hour *from* the exterior surface of a l for 1 square foot of surface, and a difference of 1° Fahrenh of temperature between the exterior and int

= Coefficient of cond y of unities of heat which will be pass re foot of wall 1 foot thick for 1° Fahr rence of ature,

	K		C
Paris freestone	1·84	..	0·5400
Common brick	1·84	..	0·4588
ster of Paris	1·64	..	0·4025
te marble	1·84	..	0·4723
Glass	1·84	..	0·1822
Fir wood	1·64	..	0·1147
Oak wood	1·64	..	0·2159
Cork	1·43	..	0·0628
Woollen blanket	1·23	..	0·0574
Cotton waste	1·21	..	0·0640
White calico	1·48	..	0·0945*

For metallic substances M. Péclet gives the following data, remarking that within the limits of practice the thickness of the medium produces no sensible difference of effect.

Unities of heat passed in one hour through one square metre for each 1° centigrade difference of temperature,

Cast iron	9·90	unities.
Sheet iron, in plates	3·93	„
Brick 0^m one inch thick	3·85	„

* These numbers are obtained from Péclet's Tables by multiplying the value of K by 0·2045, and of C by ·6747.

Or in English measures for one square foot of surface and 1° Fahrenheit,

Cast iron.....	2·0250	Unities. (English).*
Sheet iron, in plate	0·8087	„ „
Brick four inches thick	0·7873	„ „

(50.)—As an example, let us suppose the case given by Mr. Greenwell, and before referred to.

When $T = 56°{\cdot}5$
$t = 138{\cdot}0$ $\therefore t - T = 81{\cdot}5.$

$Q = 476$ cubic feet per second at an assumed temperature of 65°.

$P = 28$ feet $= 4{\cdot}66$ fathoms.

$$W = 0{\cdot}08657\ Q\ \frac{459}{459 + 65} = 0{\cdot}08657 \times 476 \times \frac{459}{524}$$

And let us suppose the shaft lined with 4½ inches of brick-work, and that the heat which traverses the brick-work is conveyed away by the earth as rapidly as it would be by the contact of air at the same temperature, viz., by 56°·5,

then for brick-work

$$K = 1{\cdot}84$$
$$C = 0{\cdot}4588$$
and $e = 4\frac{1}{2}$ inches $= {\cdot}375$ feet.

Then $t - T = 81{\cdot}5$

$$\frac{K\,C\,P}{26{\cdot}69\,W(Ke + C)} = \frac{1{\cdot}84 \times 0{\cdot}4588 \times 4{\cdot}66 \times 524}{26{\cdot}69 \times 0{\cdot}08657 \times 476 \times 459 \times (1{\cdot}84 \times {\cdot}375 \times 0{\cdot}4588)}$$
$$= 0{\cdot}0027258$$

Therefore [19] $\theta = 81{\cdot}5 \left(1 - \frac{1}{2{\cdot}718^{0{\cdot}0027258\ x}}\right)$

If $x = 65$

$$\theta = 81{\cdot}5 \left(1 - \frac{1}{2{\cdot}718^{{\cdot}1773}}\right) = 81{\cdot}5\ (1 - 0{\cdot}8376) = 81{\cdot}5 \times {\cdot}1624$$
$$= 13°{\cdot}24$$
$$\therefore t - \theta = 138 - 13{\cdot}24 = 124{\cdot}76$$

If we had found θ from the equation [18] which takes m into account, we should have obtained a value of $\theta = 14°{\cdot}02$, and $t - \theta = 123{\cdot}98$, which are so near the former values as to show the small influence of m upon the result, and that practically we may use the equation [19] without any error of consequence.

* A unity of heat is that quantity which would raise 1 lb. of water, 1 degree of Fahrenheit.

(51.)—As a second example, we will suppose the same shaft lined with a thin casing of wrought iron filled between with 2 inches of cotton waste.

It is obvious we may neglect the effect of the iron, inasmuch as its conducting power is so far in excess of the cotton waste that the latter alone will limit the passage of heat, we shall therefore have

$$K = 1{\cdot}21$$
$$C = 0{\cdot}064$$
$$e = 2 \text{ inches} = 0{\cdot}1666 \text{ ft.}$$
$$t - T = 81{\cdot}5$$

$$\therefore \frac{K\,C\,P}{26{\cdot}69\ W\,.\,(K\,e + C)} = \frac{1{\cdot}21 \times 0{\cdot}064 \times 4{\cdot}66 \times 524}{26{\cdot}69 \times 0{\cdot}08657 \times 476 \times 459 \times (1{\cdot}21 \times 0{\cdot}1666 + 0{\cdot}064)}$$

$$= 0{\cdot}00112$$

$$\therefore \theta = 81{\cdot}5 \left(1 - \frac{1}{2{\cdot}718^{\cdot 00112\ x}}\right)$$

and if $x = 65$ fathoms

$$\theta = 81{\cdot}5 \left(1 - \frac{1}{2{\cdot}718^{\cdot 0728}}\right) = 81{\cdot}5\,(1 - {\cdot}9298)$$

$$= 5{\cdot}721$$

(52.)—It thus appears that the respective losses of temperature would be as follows:—

Actual observation	47°
Formula [7]	47°
„ [9]	47°
4½ inch brick lining	13°·24
2 inch cotton waste	5°·72

And the respective temperatures at sixty-five fathoms from bottom,

Actual observation	138 — 47	= 91°
4½ brick lining	138 — 13·14	= 124°·76
2 inch cotton waste	138 — 5·72	= 132°·28

(53.)—Having thus shown the temperature which would be derived from lining upcast shafts, we must leave it in the hands of practical men to devise the means for carrying the system into effect, expressing, however, a decided conviction that in most instances no practical difficulty would be met with which might not be easily overcome.

We are inclined to think that a double sheet iron casing, filled between with cotton waste or patent felt, and fixed by light angle irons would be easily applied and most effective, and we would suggest to the members

of the Institute the propriety of making such an experiment in some of the shafts under their charge.

In doing so great care must be taken to prevent the entrance of water into the shaft, which might, we conceive, be easily accomplished by means of a single layer of asphalted felt next the external casing of iron, or, possibly, this external casing might be dispensed with altogether and the asphalted felt used in its stead.

The advantage of keeping the water out of the shaft would be felt not only in the increase of average temperature, but in an increased durability of ropes, timber, and other materials used in the shaft.

INTEGRATION OF THE EXPRESSION IN SECTION (35).

BY MR. C. A. BROOKS.

To integrate $d\theta - b\theta\, d\theta + n\theta\, dx = n s\, dx + n m x\, dx$

This may be put under the form

$(1 - b\theta)\, d\theta + (n\theta - n s - n m x)\, dx = 0$ .....(A)

Now, if we have an expression of the form

$P\, dx^1 + Q\, dy = 0$ P and Q being homogeneous functions of x^1 and y, by dividing by x^1, we get

$$F.\left(\frac{y}{x^1}\right) dx^1 + f.\left(\frac{y}{x^1}\right) dy = 0$$

the integral of which is

$$\text{Log. } x^1 = -\int \frac{d\, z f.z}{F.z + z f.z} \text{ when } z = \frac{y}{x^1}$$

Let now in (A) $1 - b\theta = x^1$

$$n\theta - n s - n m x = y$$

then $dx^1 = -b\, d\theta$ or $d\theta = -\frac{dx^1}{b}$

$$dy = n\, d\theta - n m\, dx \text{ or } dx = \frac{n\, d\theta - dy}{n m}$$

$$= -\frac{n\, dx^1 + b\, dy}{b n m} \text{ by substituting for } d\theta$$

its value $-\frac{dx^1}{b}$

Hence the equation A becomes

$$-\frac{x^1 dx}{b} - y\left(\frac{n\, dx^1 + b\, dy}{b n m}\right) = 0$$

or $(n m x^1 + y n)\, dx^1 + b y\, dy = 0$

and dividing by x^1 and writing z for $\frac{y}{x^1}$

$(n m + n z)\, dx^1 + b z\, dy = 0$

$\therefore F.z = n m + n z$

and $f.z = b z$

$$\therefore \text{Log. } x^1 = -\int \frac{dz f.z}{F.z + z f.z} = -\int \frac{b z dz}{m n + n z + b z^2}$$

$$\text{or } -\frac{1}{b} \text{Log. } x^1 = \int \frac{z dz}{m n + n z + b z^2}$$

Now, the value of this integral will depend upon whether $n^2 - 4 m n b$ is positive or negative.

If it be positive, we will have

$$-\frac{1}{b} \text{Log. } x^1 = \frac{1}{2b} \text{Log. } (m n + n z + b z^2)$$

$$-\frac{n}{2b\sqrt{n^2 - 4mnb}} \cdot \text{Log.} \frac{2bz + n - (n^2 - 4mnb)^{\frac{1}{2}}}{2bz + n + (n^2 - 4mnb)^{\frac{1}{2}}} + C \ldots \text{(B)}$$

and if $n^2 - 4 m n b$ be negative

$$-\frac{1}{b} \text{Log. } x^1 = \frac{1}{2b} \text{Log. } (m n + n z + b z^2)$$

$$-\frac{n}{(4mnb - n^2)^{\frac{1}{2}}} \cdot \tan.^{-1} \frac{2bz + n}{(4mnb - n^2)^{\frac{1}{2}}} + C^1 \ldots\ldots\ldots \text{(C)}$$

In which expressions $x^1 = 1 - b\theta$

$$z = \frac{n\theta - ns - nmx}{1 - b\theta}$$

The value of C and C^1 may be found by observing that θ and x vanish together, or $x^1 = 1$ when $z = -ns$

Consequently, to find C we have

$$0 = \frac{1}{2b} \Big(\text{Log. } (-n^2 s + b n^2 s^2)$$

$$-\frac{n}{2b(n^2 - 4mnb)^{\frac{1}{2}}} \cdot \text{Log.} \frac{-2bns + n - (n^2 - 4mnb)^{\frac{1}{2}}}{-2bns + n + (n^2 - 4mnb)^{\frac{1}{2}}}$$

which being subtracted from B, will give the corrected value of the expression.

The value of C^1 in (C) may be similarly found.

As, however, these expressions are extremely complicated, the following method may be found preferable,

Let $\theta = Ax + Bx^2 + Cx^3 + Dx^4 + \&c.$

$\therefore d\theta = A dx + 2Bx dx + 3Cx^2 dx + \&c.$

Hence the expression $(1 - b\theta) d\theta + (n\theta - ns - nmx)dx$ becomes

$(1 - bAx - bBx^2 - bCx^3 - \&c.)(A + 2Bx + 3Cx^2 + \&c.)dx$
$+ (nAx + nBx^2 + nCx^3 + \&c.)dx - nsdx - nmxdx = 0$

and dividing by dx and making the several co-efficients of like powers of $x = 0$ we get $A - n s = 1 \therefore A = n s$

also $-b A^2 + 2B + n A - n m = 0$

$$\therefore B = \frac{n(m - n s + b n s^2)}{1.2.}$$

also $-b A B - 2 b A B + 3 C + n B = 0$

$$\therefore C = \frac{n^2 (3 b s - 1)(m - n s + b n s^2)}{1.2.3}$$

and similarly for the rest

and therefore

$$\theta = n s x + \frac{n(m - n s + b n s^2)}{1.2} x^2 + \frac{n^2(3 b s - 1)(m - n s + b n s^2)}{1.2.3} x^3 + \&c.$$

Now, since n is a small fraction and b s and m also less than unity, it will be sufficient to take the first three terms of this series from which the value of n might be determined, either by approximation or by the solution of a cubic equation—

For the average loss we should have

$$\int \frac{\theta \, dx}{\text{depth}} = \int \frac{(A x + B x^2 + C x^3 + \&c.)}{\text{depth}} dx$$

$$= \frac{\frac{A}{2} x^2 + \frac{B}{3} x^3 + \frac{C}{3} x^3 + \&c.}{\text{depth}}$$

Another approximate expression may be found for θ by a different process, which gives

$$(1 - b s) \text{Log.} \frac{s}{s - \theta} + b \theta = n x - \frac{m}{n s} (\text{Log.} (1 - n x) + n x)$$

or if $m = 0$

$$\text{Log.} \frac{s}{s - \theta} + \frac{b \theta}{1 - b s} = n x$$

$$\text{Log.} s - \text{Log.} (s - \theta) + \frac{b}{1 - b s} \cdot \theta = n x$$

$$\therefore \frac{b}{1 - b s} \cdot \theta - \text{Log.} (s - \theta) = n x - \text{Log.} s$$

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(10.)—Effect of increase of d . D . T . θ and t being constant.
(11.)—If d be increased by δ.

Increase of ventilating power $= \delta \left(\frac{1}{459 + \theta} - \frac{1}{459 + t}\right) \times 39{\cdot}74$

which is positive or negative according as $\theta \lessgtr t$.
(12.)—This conclusion, though obvious as regards furnace ventilation, is less so as regards other systems.
(13.)—*2nd Case.*—(D + d) constant, but D decreasing and d increasing simultaneously, ventilating power increased, if

$$\frac{t - \theta}{459 + t} > \frac{\theta - T}{459 + t}$$

(14.)—When $\theta > t$ the variation will always diminish the ventilating power.
(15.)—*3rd Case.*—Shafts at same bank level and connected by a series of rises and falls.
Ventilating column is

$$= 39{\cdot}74 \left\{ \left(\frac{D}{459 + T} + \frac{F_1}{459 + T_1} + \&c.\right) - \left(\frac{R_1}{459 + \theta_1} + \&c. + \frac{d}{459 + t}\right) \right\} [2]$$

(16.)—If the temperature of the workings be uniform, this becomes expression [1].

In which case the conclusions as to the effect of varying the depths of the shafts remain as above.

(17.)—Where $t > \theta$ the maximum effect accompanies the maximum depth of downcast shaft.

(18.)—*4th Case.*—Shafts at different bank levels.

Ventilating column

$$= 39{\cdot}74\left(\frac{D}{459+T}-\frac{D-(d+\Delta)}{459+\theta}-\frac{d}{459+t}\right) \ldots\ldots\ldots [4]$$

(19.)—Introduction of difference of barometric pressure at mouths of shafts into [4], giving rise to the expression

$$39{\cdot}74\left(\frac{D-\Delta}{459+T}-\frac{D-(d+\Delta)}{459+\theta}-\frac{d}{459+t}\right) \ldots\ldots\ldots [5]$$

(20.)—Or more accurately,

$$39{\cdot}74\left(\frac{D}{459+T}-\frac{\Delta}{459+T^1}-\frac{D-(d+\Delta)}{459+\theta}-\frac{d}{459+t}\right) \ldots [6]$$

$$=\frac{39{\cdot}74}{459+\theta}\left(\frac{D(\theta-T)}{459+T}-\frac{\Delta(\theta-T)}{459+T^1}-\frac{d(\theta-t)}{459+t}\right) \ldots\ldots [6\,a]$$

(21.)—The introduction of Δ does not affect the conclusions arrived at as regards the effect of variation of the length of shafts.

(22.)—Convenience of the expressions

[1], [2], [3], [4], [5], [6], [6 a].

(23.)—Example of case of Backworth Colliery.

(24.)—Question of increase of furnace power to give the same average temperature in long and short upcast.

(25.)—Investigation of formulæ for cooling power of shaft,

$$\theta = \frac{aP}{Q}\cdot\frac{\frac{m}{2}x^2+(t-T)x}{1+\frac{aP}{Q}x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [7]$$

(26.)—More correct formula is

$$\theta=(t-T)+mx-\frac{m}{\frac{aP}{Q}}+\left\{\frac{m}{\frac{aP}{Q}}-(t-T)\right\}\epsilon^{-\frac{aP}{Q}x} \ldots\ldots\ldots [9]$$

(27.)—Investigation of value of $\frac{aP}{Q}$ from first series of observations given in Mr. Greenwell's work on Mining Engineering.

(28.)—Reduction of [9] to $\theta = (t-T)\left(1-\frac{1}{\epsilon^{nx}}\right)$ .....[8a]

(29.)—Solution by approximation to obtain value of

$$n = \frac{a P}{Q} = 0{\cdot}012 \text{ nearly,}$$

(30.)—Computation of values of θ to various values of x from equation [9]

(31.)—Table of computed and observed values.

(32.)—Computation of value of $\frac{a P}{Q}$ from the same data as in (28) by means of equation [7]

$$\text{whence } \frac{a P}{Q} = {\cdot}01842$$

computed values of θ from equation [7]

(33.)—Comparison of computed with observed values by means of curves, shewing that the actual observation gives a greater loss than the formula.

(34.)—Probably caused by water in shaft: need of further investigation so as to see how far the loss may be reduced to the natural law of cooling, represented by formula [9].

(35.)—This formula does not accurately represent this law, as we ought to take into account the variation of the velocity of the air in the shaft, which would give rise to the differential equation

$$d\theta - b\theta\, d\theta + n\theta\, dx = n s\, dx + n m x\, dx;$$

any error, however, arising from the use of equation [9] will only go to diminish rather than exaggerate the results of the comparison which we shall make, and, therefore, our conclusions would be still more strongly borne out had we used the integral of the last expression.

(36.)—By means of [9] the value of t to give any average temperature in the shaft may be found, and if an equation were obtained representing the actually observed law of cooling, then from it, in like manner, a value of t might be obtained, giving the same average temperature, so that by a comparison of the two we should get the actual furnace power lost by the bad condition of the shaft, or its excess of cooling power beyond that indicated by the natural law.

(37.)—Investigation of empirical equation to represent observed values of θ in terms of x

$$\theta = \frac{0{\cdot}12704\, x^2 + 4{\cdot}3731\, x}{1 + 0{\cdot}09544\, x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [11]$$

Computed values from the equation compared with actually observed values.

(38.)—Deduction from equation [9] of mean loss and resulting equation

$$\text{mean loss} = s + \frac{m}{2}d - \frac{m}{n} + \left(\frac{1 - e^{-nd}}{d}\right)\left(\frac{m}{n^2} - \frac{s}{n}\right) \ldots [14]$$

(39.)—Or, from equation (11),

$$\text{mean loss} = A\left(\frac{d}{2C} - \frac{1}{C^2} + \frac{\log.(1 + Cd)}{C^2 d}\right) + B\left(\frac{1}{C} - \frac{\log.(1+Cd)}{C^2 d}\right) [15]$$

(40.)—Numerical example of computing mean loss from these expressions and reduction of same to effect on ventilating column.

(41.)—This result is much below the reality in consequence of $\frac{a\,P}{Q}$ having been calculated from an ill-conditioned shaft, but it shows the comparison in such a shaft.

(42.)—So great a loss by cooling, *i.e.*, nearly 50 per cent, demands serious attention.

(43.)—Necessity of observations to determine the values of the constants in the above equations, and especially in shafts free from extraordinary cooling causes, and in shafts in which precautionary measures have been taken to prevent cooling.

(44.)—Investigation of expression for initial temperature in terms of mean temperature

$$t = \frac{d \cdot n(T - t) + \frac{m\,n}{2} \cdot d^2 - m\,d + (1 - e^{-nd})\left(\frac{m}{n} + T\right)}{1 - e^{-nd}} [16]$$

or from 15

$$t = \frac{C\,d\,(T - T) + A\left(\frac{d^2}{2} - \frac{d}{C}\right)}{\text{Log. } (1 + C\,d)} + \frac{A}{C^2} + T \ldots\ldots [17]$$

(45.)—Comparison, by means of formula [16], of initial temperatures required to give a mean temperature of 110° in the shafts A B and G F, in section (25).

(46.)—Respective temperatures 146° and 154½°, and, supposing air from returns to be 58½ we should require an increase of furnace power of about 10 per cent.

(47.)—Practically the gain would be greater.

(48.)—Investigation of an expression to determine, *a priori*, the amount of cooling in a shaft, when lined with non-conducting material,

$$\theta = (t - T) + m\,x - \frac{m \times 26{\cdot}69\,W(K\,e + C)}{K\,C\,P}$$

$$+ \left(\frac{m \times 26{\cdot}69\,W(K\,e + C)}{K\,C\,P} - (t - T)\right) e^{-\frac{K\,C\,P \cdot x}{26{\cdot}69\,W\,(K\,e\,+\,C)}}$$

or, making m = 0

$$\theta = (t - T)\left(1 - \frac{1}{e^{\frac{K C P x}{26{\cdot}69 W (K e + C)}}}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [19]$$

(49.)—Values of constants in the above expression.

(50.)—Example of application of formula [19] to a shaft with a lining of brick-work 4½ thick.

(51.)—Example of application of same formula to a lining of cotton-waste between iron plates.

(52.)—Comparison of these results with actual practice.

(53.)—Concluding remarks.

NORTH OF ENGLAND INSTITUTE
OF
MINING ENGINEERS.

MONTHLY MEETING, THURSDAY, JUNE 5, 1856, IN THE ROOMS OF THE INSTITUTE, WESTGATE STREET, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The Minutes of the Council having been read,

The PRESIDENT said, the first business before them would be the election of gentlemen proposed at the previous meeting.

The following gentlemen were then elected members :—Parker Jeffcock, Derby; Samuel Bailey Coxon, Usworth Colliery; Frederick Wilmer, Pensher Colliery.

Mr. MATTHIAS DUNN then called attention to the propriety of continuing the Annual Dinner as heretofore; upon which a brief discussion ensued, some gentlemen submitting that unless the members more generally supported the dinner it was useless to order one, while others thought if it was laid fully before the Institute some time before the General Meeting, more attention and greater support than hitherto would be given to it; ultimately Mr. DUNN moved, and Mr. H. G. LONGRIDGE seconded, that there be, as usual, a dinner at the Annual Meeting, and that the tickets be 10s. 6d. each, which motion, on being put, was carried.

The PRESIDENT then read the following letter :—

COPY OF ANALYSIS of "White Coal or Bituminous Sand, from Australia," by Wm. Herapath, Esq., F.C.S., dated Bristol, Feb. 4, 1856, for Messrs. Miles and Kington.

GENTLEMEN,—The Australian mineral you entrusted me with for analysis I find composed as follows, in 100 parts :—

Volatile bitumen, containing a little water	27·5	
Carbon left after a red heat	5·4	
Silica, with a little sulphate of lime	67·1	
		100·0

As the volatile matter comes over as a bitumen and not as a gas, it is questionable whether it can be advantageously employed except as a poor substitute for fuel. It is barely possible that if a large quantity of the distilled bitumen were obtained by distillation, that some processes might extract a useful ingredient from it, but this would require a considerable expenditure of time, and many experiments. It would certainly not do for the manufacture of gas.

I remain, Gentlemen,

Yours respectfully,

(Signed) WM. HERAPATH, F.C.S.

The PRESIDENT next intimated that there was nothing remaining to be disposed of except the papers of Mr. G. C. Greenwell and Mr. J. A. Longridge, and he now called upon Mr. Greenwell to read his paper.

Mr. GREENWELL then read a paper "On the Working of Thin Seams of Coal, with Observations on Long Wall and Board and Pillar Work;" after which,

Mr. LONGRIDGE read his paper "On certain Changes which take place in the Condition of the Air during its Passage through the Shafts and Workings of a Mine, and their Effect upon Ventilation."

The meeting then adjourned.

ON

THE WORKING

OF

THIN SEAMS OF COAL,

WITH OBSERVATIONS ON

LONG WALL AND BOARD AND PILLAR WORK.

BY G. C. GREENWELL.

I am induced to make some remarks upon this subject by a consideration of the system of working pursued in some of the more highly favoured coal districts of this country.

In these we find that seams of coal of 2½ feet, or even more than this in thickness, are considered as unworkable to profit, and are, therefore, not only left in the mine untouched, but so little regarded as in many cases to be rendered utterly worthless, even at any future day, by the working of the more profitable seams lying in their vicinity.

I do not mean to say that I can prove that a thin seam can be worked as cheaply as a thick one; but that a thin seam can be produced as cheaply as a thick one, with even a moderate freight added thereto, I trust I shall be able satisfactorily to establish. And when we consider the enormous rapidity of increase in the quantity of coal annually required, especially in those districts which have large deposits of ironstone nearly associated with them, and when we contemplate the fact, that in some of the large seats of the iron trade, coal bountifully deposited, is already beginning to be seriously exhausted, we cannot, I think, but feel that it would be in the highest degree unwise, from a mere want of common prudence and foresight, to hasten the day when plentiful

supplies of iron ore will lose their value from the want of cheap fuel to reduce them to their metallic state.

On reference to a section of strata throughout the Newcastle coal measures, recently published, it will be seen that there are no fewer than fifteen seams of coal under two feet six inches in thickness, and varying from twelve inches to twenty eight inches, both inclusive, all considered unworkable, and amounting in the gross to twenty five feet seven inches.

The whole lies within 280 fathoms of coal strata; and when it is taken into consideration that half of the above quantity of coal would supply a demand of 20,000,000 tons annually for somewhere about 400 years, I trust that the subject will not seem unworthy of the attention of the North of England Institute of Mining Engineers.

It must not be forgotten that the day will come when the thin seams will be of greater consequence than the thick ones.

In the collieries of the neighbourhood of Bath, in the upper or house coal series are *seven workable seams*, the aggregate thickness of which is twelve feet, occasionally worked in a section of 200 fathoms of coal strata, some of the pits are even deeper, but the average depth is 140 or 150 fathoms.

Three of the seams worked vary from twelve inches to sixteen inches, and four vary from two feet to two feet four inches.

It is not necessary in this place to enter into details of machinery or of underground or upperground transit, but, as I conceive, simply to describe the mode and cost of getting the coal and of making underground roads, as all other expenses can of course be conducted as cheaply in thin seams as in thick ones.

In order as fully as possible to show the cost of the above, I shall not take an average of seams, but show the costs in what are termed the thin seams and thick seams severally.

The whole of the coal is worked the "long way," and, according to the fancy of the manager, either by a series of heads driven on the level of the seams, one to the rise of another, as in *Fig.* 1, or driven on the rise of the seams, each having a road formed up its middle as in *Fig.* 2.

Often, however, the strata are so faulty, and the rise so variable in direction and amount, that no regular system can be pursued, and then the heads are driven as most convenient. When the heads are driven on the level, the lowest road would have the coal along its deep side, unless a strip were worked out along with the head; in practice this is essential to the maintenance of the road, for with a coal side the roof is always

found to break to a considerable extent, and to require a constant renewal of timber; whereas, under the system adopted, no timber at all is most frequently required.

When the heads are driven on the rise, a drift, or level head is first driven, with the same precaution of removing the coal for a few yards on each side of what is intended to be the permanent road.

Having, in the North of England, often seen the difficulty of keeping up the roof in narrow places, and particularly in deep pits, I would suggest the trial of the plan described; the sides of the road being (as in Somersetshire) stowed up with any stone that can be got, from the roof or otherwise.

When I first commenced practice in Somersetshire, I found all the roads in the goaf, and the expense of their maintenance, in many cases, considerable. I thought that by leaving a barrier of coal on the side of these roads, the expense of their support might be moderated, and as an experiment, I left thirty yards of coal on each side of a main road at the depth of 126 fathoms, the thickness of the seam being two feet two inches.

The result did not answer my expectations; the thill heaved worse by far than before, and, in fact, until there was no more soft thill to heave, the whole having been picked up to keep the necessary height of road way, and then the roof began to fall. The experiment was tried for 100 yards, for a period of six months, and then discontinued, the whole of the coal being thenceforth removed. Beyond the 100 yards (and where now in work) the roof is firm; the coal is good and the country quiet.

To describe more particularly, the thickness of coal is two feet two inches, the roof is blue metal, and the thill soft black metal about eight feet in thickness. Immediately under the coal the thill is so soft as to be undermined in. I then directed the pillars to be entirely removed from the sides of the main road, which is now in progress; already the place is much easier, and I have no doubt when they are gone, the road will be as quiet as the rest of the roads are.

I may repeat that before the roof began to break all the softest of the thill had been picked up, and this may throw some light upon the breakage of roofs.

I shall now proceed to the question of the hewing or getting of the coal, and its drawing to the main roads.

If we take the gross quantity of coal obtained in a certain time by a given amount of manual labour, as a criterion, it will not require much argument to show that the thicker the seam, *ceteris paribus*, the more coal will be worked.

But we must give due consideration to the fact, that in general it is our chief object to produce large coal, and that there are economical and wasteful modes of effecting this, as well as of conducting other matters.

In order to shew what can be done by the long way of working, I give the area worked, thickness, and absolute produce of the several seams of coal at Radstock in the year 1855, from which it appears that a gross mine content of 122,082 tons produced of saleable coal 99,863 tons, besides 8,840 tons required for colliery consumption.

SEAMS.	THICKNESS.	AREA WORKED.	CONTENTS PER ACRE.	GROSS CONTENTS OF AREA WORKED.
	ft. in.	Acres.	Tons.	Tons.
Great Vein	2 2	2·6955	3370	9,083
Top Little Vein	1 4½	7·6527	2139	16,369
Middle Vein	2 0	5·5724	3111	17,335
Slyving Vein.....	2 3½	7·9026	3565	28,172
Under Little Vein	1 2	8·2756	1815	15,020
Bull Vein	2 3½	10·1272	3565	36,103
Total.....	....	....	....	122,082

Which is accounted for as follows:

SALES.	TONS.	PER CENT.
Round	89,755	73·52
Small	10,108	8·27
Sold.....	99,863	81·79
Colliery Consumption	8,840	7·24
Loss underground at Faults, and small Coal not landed.....	13,379	10·97
Total.....	122,082	100·00

I am not prepared to say how much of the above 10·97 per cent. consisted of small coal purposely stowed underground, but imagine that it would not be less than half, reducing the quantity actually lost in

working to 5·48 per cent. According to the board and pillar practice of working seams of coal from 4 to 5 feet in thickness, I believe that it will be found that 11 per cent. at least, is lost underground, leaving 89 per cent. as the quantity drawn to bank in altogether work, of which, on the average, not more than 66 per cent., or 58·74 per cent. of the entire mine is sold as merchantable round coal.

And from a comparison of the above calculations, it will appear that 58·74 feet in thickness, made up of the thin seams described and worked by the long wall, produce as much round coal as 73·52 feet in thickness made up of seams four or five feet thick, worked by the board and pillar method.

A thin seam worked by board and pillar makes more small than a thick one, and it may, therefore, be safely said that by the long wall mode as much round coal can be got out of a seam of coal two feet in thickness, as by the board and pillar method out of a seam two feet nine inches, or possibly three feet.

Each head of coal is usually (where practicable) made about sixty yards in width, in which are placed four men. If the head is driven on the level, there may be ten yards of dip side and fifty yards on the rise side of the main road, which is made waggon-way size into the face.

In order to bring the coal from the high side to the waggon-way, branch-ways, or, as they are called, twin-ways, of smaller size, or three and a half feet in height are also carried up to and dividing the face so as to have about ten yards of face on each side of the twin-way.

If the head is driven to the rise, the waggon-way is made up the centre of the head, also into the face, and a branch or twin-way carried from each side into the face as above.

In bringing the coal to the waggon-way we have, therefore, three distinct sets of operations.

1. *The Hewing or Breaking.*—This is performed by undermining, or, as it is called, "benching," in a pricking or swad, which usually is found of the thickness of two or three inches under the seams of coal, it is sometimes thicker and sometimes thinner.

The benching is usually worked under the coal, from eighteen inches to two feet along the face, when the coal falls without the use of gunpowder or wedges; a few inches of the roof often fall with the coal.

The breaker then secures the roof and throws back the stone or rubbish into the goaf behind; he also forms pillars of stone occasionally for the support of the roof, but this more properly belongs to another department.

The prices paid for the above are, for seams averaging two feet two

inches, about 1s. 1d. per ton; and for seams averaging one foot three inches, 2s. 2d. per ton, paid on the produce of round coal.

2. *Carting.*—This includes bringing the coal from where it has fallen, to the twin-ways. It is in the case of the thin veins commonly drawn on boards, and in the thicker ones on puts or sledges. The persons employed at this work also pack the coal upon the carriages for the purpose of being taken along the twin-ways to the waggon-ways.

The cost of carting in the thick seams amounts to about 8d., and in the thin seams to 1s. 2d. per ton on the round coal sold.

3. *The Twin-work* consists of bringing the coal along the twin-ways to the waggon-ways; its cost under favourable circumstances, or where the dip of the seams is moderate, and their regularity as great as in the Newcastle coal-field, is about 3d. per ton on the round coal, but where the inclination is very great or the ground faulty it often costs more.

If to the above items be added the cost of pillaring in the face, making the twin-ways, waggon-ways, and air-ways, and pillaring on the sides of these, also the removal of rubbish out of thin seams into thick ones, all of which expenses are consequent on the working of thin seams of coal in the long way, we arrive at certain amounts, beyond which expenses are common to seams of coal of whatever thickness and however worked.

These expenses are as follows:—

1. *Making Roads.*—These consist of twin-ways, air-ways, and waggon-ways, and the pillaring up of their sides, and the cost of this for the thick seams is 5¼d. per ton, and for the thin ones 6½d. per ton, on the round coal sold.

2. *Deading.*—Which comprises maintaining roads and air-ways, upon which, until they become settled, there is a great deal of heaving and lowering way, pillaring up stone in the face, removing rubbish from them into thick seams, &c., &c., and costs in both about 7d. per ton on the round coal sold.

The following is an abstract of the above costs:—

		THICK VEINS.		THIN VEINS.	
		Per Ton.		Per Ton.	
		s.	d.	s.	d.
1.	Breaking	1	1	2	2
2.	Carting	0	8	1	2
3.	Twinwork	0	3	0	3
4.	Making Roads	0	5¼	0	6½
5	Deading	0	7	0	7
	Total	3	0¼	4	8½

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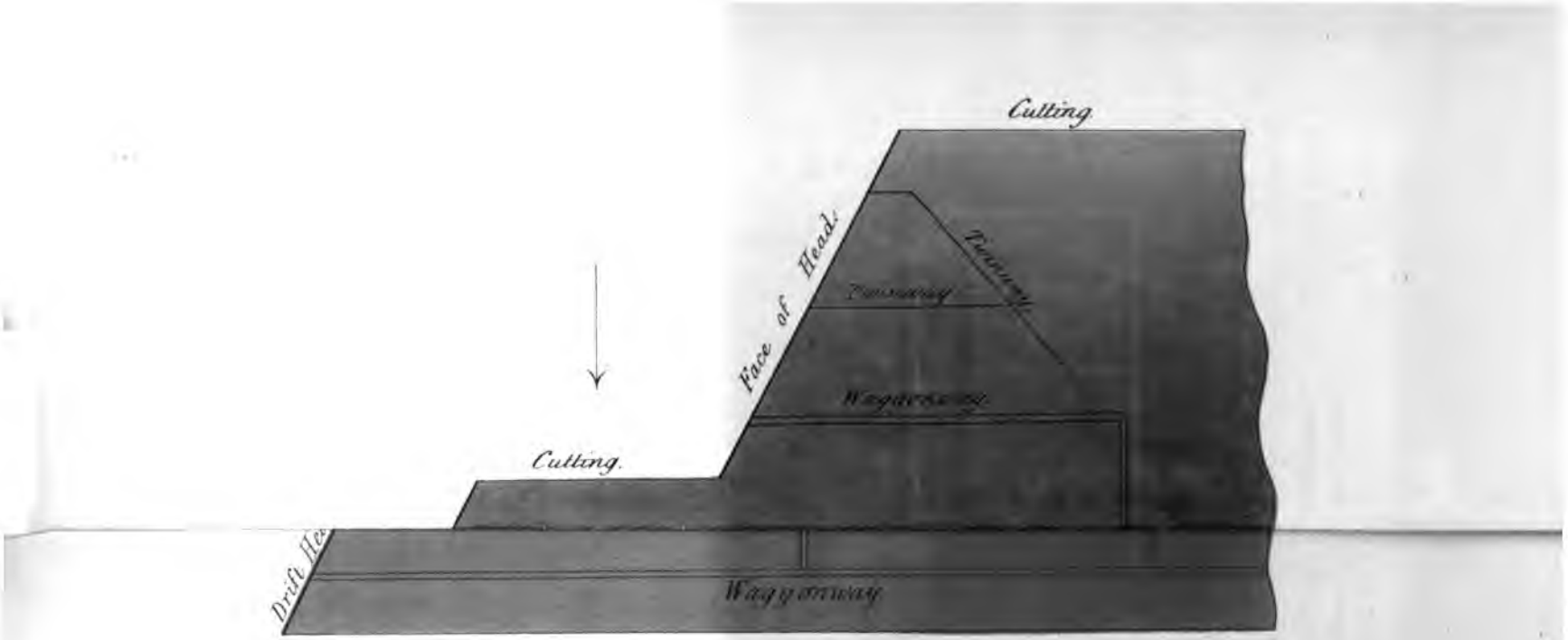


Fig. 2.—Heads working to the Rise.

Scale, 30 Yds.=1 Inch.

Reid Lith. 40 Pilgrim St. Newcastle on Tyne

I shall now compare with the above the cost of working by the board and pillar method upon round coals, an average seam of coal, say four feet in thickness, and similar in hardness to those above described, taking the items of labour which are parallel with the above into calculation. I take the average costs of working at an average Five-quarter, Low Main and Hutton Seam Colliery of the North of England, which are as follows:—

		Per Ton.	
		s.	d.
1.	Hewing and Narrow Work ..	1	10
2.	Putting and Helping-up	0	4½
3.	Deputy Work	0	2
4.	Making Waggon-ways	0	2
5.	Shift Work	0	1¾
	Total	2	8¼

From this it appears that by the long way of work a seam of coal two feet two inches in thickness, can be worked within 4d. a ton of the cost of a four feet seam, worked by board and pillar, and a seam fifteen inches thick at about 2s. per ton higher, calculated upon round coals in both cases.

Or to place the matter in a stronger light, a seam of coal two feet two inches thick, near to the shipping place, could be put on board as cheap as a four feet seam half a dozen miles from it. Thirty miles of shorter carriage would probably make it worth while to work the fifteen inch seam.

The relative ages of the work-people employed in the thin seams is interesting, and shows the number of young persons to form a large proportion of the whole.

The following table presents the number of work-people employed underground in the East Somersetshire Collieries, with the proportion employed during each quinquennial period, (1855).

AGES.	NUMBER.	PER CENTAGE OF EACH AGE.
10 to 15.....	621	23·381
15 to 20.....	458	17·244
20 to 25.....	335	12·613
25 to 30.....	279	10·505
30 to 35.....	218	8·208
35 to 40.....	189	7·116
40 to 45.....	170	6·400
45 to 50.....	128	4·819
50 to 55.....	100	3·765
55 to 60.....	83	3·125
60 to 65.....	50	1·882
65 to 70.....	15	0·564
70 to 75.....	10	0·376
75 to 80.. ...	0	0·000
Total	2656	100·000

The quantity of large and small coal worked in the district in 1855 was about 400,000 tons, which is equal to 150½ tons per head.

According to Mr. T. Y. Hall's calculations, the underground labour of the North of England produced in 1844, 382¼ tons per head, and in 1854, 494 tons.

I do not observe that the more recumbent position of the workmen in the thin seams seams produces any injurious effects physically, nor do I think that any comparison between the working classes of these seams with those who are employed in thicker ones is by any means disadvantageous to the former class.

The number of fatal accidents during the year ending June 30, 1855, was, in the East Somersetshire district, 5, as appears from the report of the Government Inspector, Mr. H. Mackworth.

This is equal to 1·882 per thousand persons employed, or 1 for every 80,000 tons of coal.

Four of the above were shaft accidents, equal to 1·506 per thousand persons, and one was caused by fall of roof, equal to 0·376 per thousand. I believe, however, that since the above date only one life has been lost in the district, that also in a shaft.

The above does not compare unfavourably with the return of the Government Inspector for the North of England, Mr. Dunn. According to his report for 1854, the number of fatal accidents was 104, which is equal to 3·851 per thousand persons employed, or 1 for every 128,201 tons of coal.

Thirty-three of the above deaths were caused by falls of stone and

coal, equal to 1·222 per thousand persons, and twenty were shaft accidents, equal to 0·747 per thousand, and equal together to 1·969 per thousand, or about the same from these causes as in East Somersetshire.

There is, undoubtedly, less liability to accident from fall of roof in a thin seam than in a thick one, when the quantity of coal worked is in proportion to the thicknesses of the two seams; otherwise, for the same quantity of coal, there is twice or thrice as much roof to work under in the former than in the latter instance, and, consequently, liability to accident must be greater.

I believe also, there is considerably less risk of accident in working by the long way than by the board and wall. By the former method new and firm roof is exposed daily, the roof of two days old being stowed up and supported behind, and the space between the pillaring and the face, probably not exceeding four or five feet, and even that propped with timber where necessary, whereas, in the board and pillar mode, the same roof is almost always exposed for a month and often much longer, supported by timber only. In working off the pillars, the danger is certainly much greater than in long work.

ON CERTAIN CHANGES

WHICH TAKE PLACE IN

THE CONDITION OF THE AIR

DURING ITS

PASSAGE THROUGH THE SHAFTS AND WORKINGS OF A MINE,

AND THEIR EFFECT UPON VENTILATION.

BY J. A. LONGRIDGE.

PART I.—THERMOMETRIC CHANGES.

(1.)—The general question of the passage of air through the workings of a mine, and the laws according to which the resistance to its motion is governed, have been very ably treated by Mr. Atkinson, in a paper brought before the Institute, and now published in the Third Volume of the "Transactions."

There are, however, certain questions upon which that gentleman has barely touched, and which have, under some circumstances, so important an effect upon the ventilation of a mine that it seems desirable to enter upon their discussion with a view, first of pointing them out, and secondly, of ascertaining and reducing to formulæ, as far as possible, their specific laws of action and their comparative influence upon the general system of ventilation.

(2.)—The changes which take place in the condition of the air during its passage through the shafts and workings of a mine are of a four-fold nature.

1st.—Thermometric.

2nd.—Barometric.

3rd.—Hygrometric.

4th.—Chemical.

Each of these changes has its peculiar influence upon the state of ventilation, and some of them react upon the others.

For instance, by the alteration of temperature, which we shall see, in all cases, takes place in the air, its density is varied, but at the same time its capacity for heat, as well as its power of absorbing moisture undergoes a change, and these again react upon its density. So also the chemical changes induced by respiration, by combustion, and by exhalations of gases from the coal strata, have their specific influence both upon the density and upon the capacity for heat of the mixture which they form with the circulating air.

The complete solution of this problem is, therefore, of considerable difficulty and intricacy, and its entire embodiment in one formula would possibly be beyond our powers, but by separating these various influences and dealing with them apart, we may, perhaps, succeed in deducing consequences or relations which may be of value in giving us a clearer insight into the nature of these influences and the extent of their operations.

We may not be able in every case to present formulæ such as will accurately accord with the results of observation, and this in a considerable degree from the absence of such experimental data as are necessary to furnish us with constants applicable to our equations, or upon which we can depend, but it will not be without advantage, should this paper be the means of directing attention to such observations as may tend to complete our experimental knowledge with reference to such changes as we are about to discuss.

(3.)—We propose, at present, to confine our attention to the *Thermometric Changes* which take place during the passage of the air through the mine.

(4.)—It is a well ascertained fact that the temperature of the earth increases as we descend, and this rate of increase is variously stated by different observers.

In the reports of the British Association for the Advancement of Science, for the years 1836, 1837, 1840, and 1844, a good many observations are recorded, from which the following table has been compiled:—

		Feet.
Consolidated Mines, Cornwall	1°	in 49·6
Levant Mines	1	in 46
Tresavean Copper Mine	1	in 49
Monkwearmouth	1	in 59·36
De la Rive and Marcet experiment, near Geneva ..	1	in 59
Arago, from 15 Artesian Wells in France	1	in 46

	Feet.
Kupffen in Poggendorff Annals, XXXII.....	1 in 37
Magnus, a Well near Magdeburg.....	1 in 44
Professor Reich of Freiberg	1 in 76

Mr. Greenwell, in his recently published work on Mine Engineering, also gives the following as the result of his own observations:—

Marley Hill Colliery	1 in 41·1
Norwood Colliery, mean	1 in 37·6
Pontop Colliery	1 in 37·9
Burnopfield Colliery	1 in 36
Killingworth Colliery.....	1 in 52·1

In a former paper communicated to the Institute, we made use of the rate as ascertained at Marley Hill, and which is also the mean of Mr. Greenwell's observations, and we shall, therefore, continue the use of the same rate of increase in this paper.

(5.)—It is obvious that this variation of the earth's temperature must have an effect upon the air which passes through the workings, and that such effect must vary according to the relative depth of the workings and the heat as compared with that of the air passing through them. If the average heat of the workings exceeds that of the air at bank, then the air will reach the bottom of the upcast at a higher temperature than that at which it entered the downcast, and what is called a natural ventilation will ensue.

The amount of this may be very considerable, and our first object will be to investigate formulæ which may represent the variation of the temperature of the air as a function of the *length*, *depth*, and *inclination* of the workings, and we shall endeavour to show that in the operation of this cause alone there is abundant power to cause that superior facility of ventilation which obtains in workings situated to the dip, as compared with those to the rise of the downcast shafts.

(6.)—Before, however, proceeding in this investigation, we must refer shortly to some observations upon the subject, contained in a paper presented to the Institute by Mr. T. J. Taylor and contained in Volume III. of the "Transactions."

He states that "The comparative facility with which dip workings are ventilated is not to be accounted for on a principle of gravitation.

"Setting aside considerations of temperature, variation, and other extraneous conditions, the weight of column *below* the level of the upcast is balanced by its return column *up* to that level."

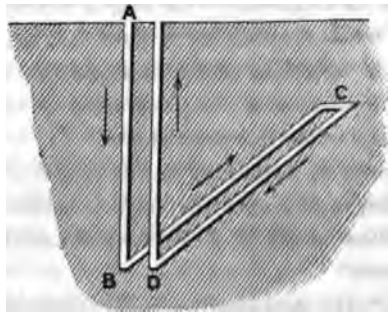
He then directs attention to the fact of the progressive lowering of the barometric column, as we proceed, along the workings in a water level, and observes that the same relative fall takes place in either ascending or descending planes, and then he concludes "that the air in the ingates is, owing to the cause assigned, and all other circumstances being alike, heavier or denser than the air in the returns." Then he continues, "That the lighter column ascends upon the dip workings upon the same principle that light or rarified air ascends a shaft, but in the rise workings the operation is reversed, the lighter column of the return, is to be *forced* downwards, and these cause a loss of motive power equal to the mechanical effort required for the purpose."—*Trans. Min. Inst., Vol. III., p. 363.*

Now, we certainly cannot see how Mr. Taylor reconciles this explanation with his previous, and, as we think, correct assertion that the superior facility of ventilation is not due to a principle of gravitation, always setting aside considerations of temperature. As far as we can attach a meaning to his explanation it depends solely and entirely upon gravitation.

The air is lighter in one set of workings than in the other, and so it ascends or tends to ascend therein, but such tendency to ascend is simply and solely due to gravitation.

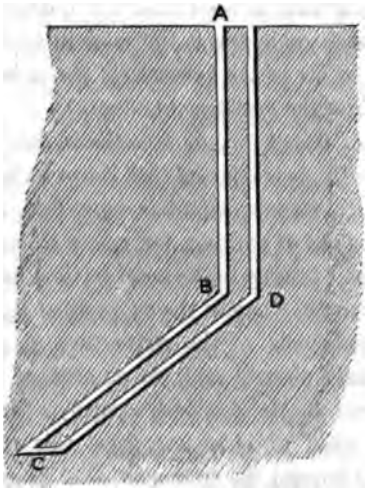
(7.)—In order to consider this question under its most simple form, we shall suppose the case of two shafts of equal depth side by side, in which the workings proceed from the bottom of the downcast to the rise and return to the bottom of the upcast, situated at the same level, *Fig.* 1, and we

Fig. 1.



shall compare this with another series of exactly similar workings proceeding from the bottom of the downcast to the dip, and returning to the bottom of the upcast, situated as before, at the same level, *Fig.* 2.

Fig. 2.



Here we have the same resistance, and *supposing the temperature of the earth to exert no influence on that of the air*, the same ventilating causes in action. Now, it is evident that in both cases the density of the air is greater between BC than between CD, and Mr. Taylor's explanation of the superior facility (or rather, the assumed superior facility, for in this case we deny that it exists,) of ventilating the system of *Fig.* 2, is that in *Fig.* 1 the denser air is going up and the lighter air is coming down, whereas in *Fig.* 2 the reverse is the case. If this were the only cause, it would clearly be the simple effect of the gravitation of the two columns of air, which, however, is contrary to what Mr. Taylor previously asserts, for he expressly states that the superior facility is not attributable to gravitation.

The error seems to arise from regarding the problem as a *statical* rather than a *dynamical* one. If we look upon it in its true light, we shall find that the work to be done is precisely the same in both cases. A certain weight of air has to be moved against a certain mean resistance, from the point B to the point D, both points being at the same level, and the distance traversed being exactly the same, consequently, it is certain that the work done is precisely the same in one case as the other. It is true that in the first case, each cubic foot of air which goes from B to C is heavier than each cubic foot which comes down from C to D, but then there are more cubic feet to come down than there are to go up; and, in *Fig.* 2, each cubic foot that descends is heavier than each cubic foot that

ascends to D, but then there are fewer cubic feet to come down than there are to go up, so that in each case the quantity moved multiplied by the weight of each cubic foot is the same in ascending as in descending, and therefore, as far as the ventilating power is concerned it makes no difference which of the systems we adopt.

The difference of density is, *by hypothesis*, due only to the drag of the mine, consequently, it is obvious that it can have no active energy in creating ventilation. To suppose it has, is, in fact, to argue in favour of the creation of force out of nothing, for, where the same weight is moved the same distance and returns to the same vertical height, the mechanical power must be the same, whereas the supposition that it is increased by any particular arrangement of the route through which it operates, is manifestly, as we have already said, the creation of force out of nothing.

(8.)—With respect to Mr. Atkinson's paper, we confess we are unable to discover from it what are his views upon this subject, and we think that he does not go beyond the statement, that in estimating the resistances of the air-ways from the barometric, or perhaps we should say, manometric, observations, which he suggests, account must be taken of the increase or decrease of density due to a dip or rise in the workings. We do not then see how Mr. Taylor differs from Mr. Atkinson, inasmuch as Mr. Atkinson appears to us to express no opinion, but before passing on we think it only right to say, that we may possibly have misunderstood Mr. Taylor's views, and if so, to express our regret for having done so.

(9.)—According to what we have premised, their should be no difference in the facility of ventilating rise and dip workings, so long as we assume no change to take place in the thermometric condition of the air. If, then, it be an ascertained fact, that there is a superior facility in the ventilation of dip workings, it follows that some change, productive of that effect, must have taken place, and we shall proceed at once to the consideration of what we believe to be the main operating cause, viz., the increase of temperature of the earth in descending, whereby the temperature of the air is increased as it passes along in contact with the surfaces of the workings.

This is the chief of the thermometric changes induced in the air, those due to the heat of lamps and animal heat being of little moment.

(10.)—We shall assume, in this investigation, that the temperature of the earth increases gradually and uniformly as we descend, and that its temperature at the surface is the same as the mean temperature of the place where the shaft is situated.

This is not strictly correct, as we must descend a certain distance before we arrive at the plane of invariable temperature, but we believe that distance to be so small, as compared with the depths with which we have to deal, that no sensible error will arise from our hypothesis, which, moreover, will in some degree render the formulæ less complex than they would otherwise have been.

(11.)—We shall, first, take a system such as is represented in *Fig.* 1, and find expressions representing,

1st.—The variation of temperature induced in the air at any point of the downcast shaft, intake, returns, and upcast.

2nd.—The final temperature at the bottom of the downcast, the end of the intake, the end of the returns and the top of the upcast.

3rd.—The mean temperature in the downcast, the intake, the return air-courses, and the upcast, and we shall then proceed to find similar expressions for the corresponding values, referring to the series of workings in *Fig.* 2.

By a comparison of these expressions we shall be able to perceive clearly and certainly what the effect of the internal heat of the earth is, not only relatively to rise and dip workings, but also absolutely with respect to ventilation in general.

(12.)—Let therefore

m = coefficient for the increase of the earth's temperature in descending.

a = a constant, the nature of which will be shown hereafter.

t = temperature of earth at surface.

θ = ditto, of air at bank.

T_1 = ditto, ditto, at bottom of downcast.

T_{2R} = ditto, ditto, at end of intake of rise workings.

T_{2D} = ditto, ditto, ditto, dip ditto.

T_{3R} = ditto, ditto, at end of return air-course of rise workings.

T_{3D} = ditto, ditto, ditto, dip ditto.

T_{4R} = ditto, ditto, at top of upcast from rise workings.

T_{4D} = ditto, ditto, ditto, dip ditto.

T_1 = mean temperature of air in downcast shaft.

T_{2R} = ditto, ditto, in intake of rise workings.

T_{2D} = ditto, ditto, ditto, dip ditto.

T_{3R} = ditto, ditto, return air-course rise workings.

T_{3D} = ditto, ditto, ditto, dip ditto.

T_{4R} = ditto, ditto, upcast shaft for rise workings.

T_{4D} = ditto, ditto, ditto, dip ditto.

d = depth of downcast shaft.
d' = ditto, upcast.
a = angle of inclination of intake.
l = length of ditto.
β = angle of inclination of return air-course.
l' = length of ditto.
e = the base of the Naperian logarithms = 2·718.

(13.)—Let now θ' be the alteration of temperature induced in the air in passing down the shaft to x, and which may of course be either positive or negative,

then $\theta + \theta'$ = temperature at x

but $t + m\,x$ = temperature of earth at x

and assuming that the variation of the temperature of the air in passing through any small portion of the shaft is proportioned to the difference of the temperatures of the earth and air at that point, which assumption is very nearly accurate for such ranges of temperature as we have to deal with, we get

$$d\,\theta' \propto \{t + m\,x - (\theta' + \theta)\}\,d\,x, \text{ or}$$

$$d\,\theta' = a\,t\,dx + a\,m\,x\,dx - a\,\theta'\,d\,x - a\,\theta\,d\,x$$

$$d\,\theta' + a\,\theta'\,d\,x = a\,(t - \theta)\,d\,x + a\,m\,x\,d\,x$$

In order to integrate this, multiply both sides by e^{ax}, where e is the base of the Napecian system of logarithms, then

$$e^{ax}\,d\,\theta' + \theta'\,e^{ax}\,a\,d\,x = a\,(t - \theta)\,e^{ax}\,d\,x + m\,e^{ax}\,a\,x\,d\,x$$

and integrating

$$e^{ax}\,\theta' = (t - \theta)\,e^{ax} + m\,a\int e^{ax}\,x\,d\,x$$

$$= (t - \theta)\,e^{ax} + m\,x\,e^{ax} - \frac{m}{a}\,e^{ax} + C$$

but when $x = 0$ $\theta' = 0$, therefore

$$0 = (t - \theta) \quad \frac{m}{a} + C, \text{ and}$$

$$C = \frac{m}{a} - (t - \theta)$$

$$\therefore e^{ax}\,\theta' = (t - \theta)\,(e^{ax} - 1) + m\,x\,e^{ax} - \frac{m}{a}\,(e^{ax} - 1)$$

$$\theta' = \left(t - \theta - \frac{m}{a}\right)\left(1 - \frac{1}{e^{ax}}\right) + m\,x \ldots\ldots\ldots\ldots \quad [1]$$

which is the equation for the increment or decrement of temperature of the air at any depth, x.

If $x = d$ then the temperature gained or lost will be

$$\theta' = \left(t - \theta - \frac{m}{a}\right)\left(1 - \frac{1}{e^{ad}}\right) + m\,d \quad \ldots\ldots\ldots\ldots [2]$$

and the temperature at the bottom of the downcast

$$T_1 = \theta + \theta' = \theta + \left(t - \theta - \frac{m}{a}\right)\left(1 - \frac{1}{e^{ad}}\right) + m\,d \ldots\ldots [3]$$

$$\text{or } T_1 = t + m\,d - \frac{m}{a} - \frac{t - \theta - \frac{m}{a}}{e^{ad}} \quad \ldots\ldots\ldots\ldots [4]$$

If the temperature of the air entering be the same as that of the earth at the top of the shaft $\theta = t$ and the expression becomes

$$T_1^{\theta = t} = t + \frac{m}{a}(e^{-ad} - 1) + m\,d \ldots\ldots [5]$$

(14.)—From [1] we may deduce the mean temperature of the downcast shaft by observing that the mean increase or decrease will be $\frac{\int \theta'\,dx}{d}$ when $x = d$, and, therefore, mean temperature of downcast

$$T_1' = \theta + \frac{\int \theta'\,dx}{d} \text{ when } x = d$$

Substituting for θ' its value [1] and writing $N = \left(t - \theta - \frac{m}{a}\right)$

$$T_1' = \theta + \frac{1}{d}\left\{ N\int dx - N\int e^{-ax}\,dx + m\int x\,dx \right\}$$

and integrating the part within the brackets, we get

$$\int \theta'\,dx = Nx + \frac{N}{a}e^{-ax} + \frac{m}{2}x^2 + C,$$

$$\text{but when } x = 0 \quad \int \theta'\,dx = 0$$

$$0 = 0 + \frac{N}{a} + 0 + C, \text{ whence}$$

$$C = -\frac{N}{a} \text{ and when } x = d$$

$$T_1' = \theta + N + \frac{N\,e^{-ad}}{a\,d} + \frac{m}{2}d - \frac{N}{a\,d} = \theta + N + \frac{N}{a\,d}(e^{-ad} - 1) + \frac{m}{2}d$$

and replacing N by its value

$$T_1' = \theta + t - \theta - \frac{m}{a} + \frac{t - \theta - \frac{m}{a}}{a\,d}(e^{-ad} - 1) + \frac{m}{2}d$$

$$\text{or } T_1' = t + \frac{m}{2}d - \frac{m}{a} + \frac{t - \theta - \frac{m}{a}}{a\,d}(e^{-ad} - 1) \ldots\ldots [6]$$

RISE WORKINGS INTAKE.

(15.)—We now proceed to the intake of the rise workings. Take y any variable distance from the bottom of the downcast,

a the angle of inclination, supposed to be uniform throughout the workings, then we shall have total rise at $y = y \sin. a$

temperature of the earth at $y = t + m\,d - m\,y \sin. a$

$$= t + m\,(d - y \sin. a)$$

Let θ'' be the temperature added to or taken away from the air in its passage to y, then temperature of air at $y = T_1 + \theta''$ (θ'' being positive or negative as the case may be), therefore,

difference of temperature of earth and air at y

$$= t + m\,(d - y \sin. a) - (T_1 + \theta'')$$

and the variation of temperature in passing through a small space dy of the workings will be

$$d\,\theta'' = a\,(t + m\,(d - y \sin. a) - T_1 - \theta'')\,dy$$

$$d\,\theta'' + a\,\theta''\,dy = a\,\{t - T_1 + m\,d\}\,dy - a\,m \sin. a\,y\,dy$$

and proceeding as before,

$$\theta'' \epsilon^{ay} = a\,\{t - T_1 + m\,d\} \int \epsilon^{ay}\,dy - a\,m \sin. a \int \epsilon^{ay}\,y\,dy$$

$$= a \left\{(t - T_1 + m\,d)\,\frac{\epsilon^{ay}}{a} - m \sin. a \left(\frac{\epsilon^{ay} y}{a} - \frac{\epsilon^{ay}}{a^2}\right)\right\} + C$$

and since $\theta'' = 0$ when $y = 0$

$$0 = a \left\{(t - T_1 + m\,d)\,\frac{1}{a} + \frac{m \sin. a}{a^2}\right\} + C$$

$$\therefore \theta'' \epsilon^{ay} = (t - T_1 + m\,d)\,\epsilon^{ay} - m \sin. a\,\epsilon^{ay} y + \frac{m}{a} \sin. a\,\epsilon^{ay}$$

$$- (t - T_1 + m\,d) - \frac{m}{a} \sin. a$$

$$\text{and } \theta'' = (t - T_1 + m\,d + \frac{m \sin. a}{a}) \left(1 - \frac{1}{\epsilon^{ay}}\right) - m \sin. a\,y \;\ldots\; [7]$$

which is the equation giving the variation in temperature at any point y of the intake rise workings,

when $y = l$ this becomes

$$\theta''^{y=l}_{R} = (t - T_1 + m\,d + \frac{m}{a} \sin. a)\,(1 - \frac{1}{\epsilon^{al}}) - m \sin. a\,l \ldots [8]$$

and the temperature at the end of the intake rise workings,

$$T_2 = T_1 + \theta''^{y=l} = T_1 + (t - T_1 + m\,d + \frac{m}{a} \sin. a)(1 - \frac{1}{\epsilon^{al}}) - m \sin. a\,l\ [9]$$

$$= t + m\,d + \frac{m}{a}\text{sin. } a - m \text{ sin. } a\,l - \frac{t - T_1 + m\,d + \frac{m}{a}\text{sin. } a}{e^{al}} \quad [10]$$

and substituting for T_1 its value [4], we get

$$T_{2R} = t + md + \frac{m}{a}\sin.a - m\,l\sin.a - \frac{\left(t - \theta - \frac{m}{a}\right) + \frac{m}{a}(\sin.a + 1)e^{ad}}{e^{al} + e^{ad}} \quad [11]$$

which is the expression for the temperature at the end of the intake rise workings.

If $a = 0$ or the strata are horizontal

$$T_{2R}^{a=o} = t + m\,d - \frac{t - \theta - \frac{m}{a} + \frac{m}{a}e^{ad}}{e^{al} + e^{ad}} \quad \ldots\ldots\ldots\ldots\ldots [12]$$

$$= t + m\,d - \frac{t - \theta + \frac{m}{a}(e^{ad} - 1)}{e^{al} + e^{ad}} \quad \ldots\ldots\ldots\ldots\ldots [13]$$

and when $\theta = t$

$$T_{2R}^{\begin{cases} a=o \\ \theta=t \end{cases}} = t + m\,d - \frac{m}{a}\frac{(e^{ad} - 1)}{e^{al} + e^{ad}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [14]$$

(16.)—We next will determine the mean temperature of the intake. Here we have, as before, mean temperature

$$= T_1 + \int_{y=o}^{y=l} \frac{\theta''\,dy}{l} = T_1 + \frac{1}{l}\int_{y=o}^{y=l} \theta''\,dy$$

and since [7] $\theta'' = \left(t - T_1 + m\,d + \frac{m \text{ sin. } a}{a}\right)\left(1 - \frac{1}{e^{ay}}\right) - m \text{ sin. } a\,y$

writing $\left(t - T_1 + m\,d + \frac{m \text{ sin. } a}{a}\right) = N$ and $m \text{ sin. } a = M$

we get mean temperature

$$T_2 = T_1 + \frac{1}{l}\int^{y=l} \{N - N\,e^{-ay} - M\,y\}\,dy$$

and integrating the part within the brackets, we get

$\int \theta''\,dy = N\,y + \frac{N}{a}e^{-ay} - \frac{M}{2}y^2 + C$, but when $y = 0 \int \theta''\,dy = 0$

therefore

$$0 = 0 + \frac{N}{a} - 0 + C, \text{ whence } C = -\frac{N}{a}$$

$$\int \theta''\,dy = N\,y + \frac{N}{a}(e^{-ay} - 1) - \frac{M}{2}y^2, \text{ and when } y = l$$

$$\int_{y=0}^{y=l} \frac{\theta'' \, dy}{l} = N + \frac{N}{al}(\epsilon^{-al} - 1) - \frac{M}{2} l, \text{ whence}$$

$$T_2 = T_1 + N + \frac{N}{al}(\epsilon^{-al} - 1) - \frac{M}{2} l \quad \ldots\ldots\ldots\ldots\ldots [15]$$

and replacing N and M

$$T_2 = T_1 + t - T_1 + md + \frac{m \sin.\alpha}{a} + \frac{t - T_1 + md + \frac{m \sin.\alpha}{a}}{al}(\epsilon^{-al} - 1) - \frac{m}{2} \sin.\alpha$$

$$= t + md + \frac{m}{a} \sin.\alpha - \frac{m}{2} \sin.\alpha l + \frac{t - T_1 + md + \frac{m \sin.\alpha}{a}}{al}(\epsilon^{-al} - 1) \ldots [16]$$

and replacing T_1 by its value, and reducing, we get

$$T_{2R} = t + md - \frac{m}{2} l \sin.\alpha + \frac{m}{a} \sin.\alpha + \frac{\left(t - \theta - \frac{m}{a}\right) + \frac{m}{a}\left(\sin.\alpha + 1\right)\epsilon^{ad}}{al\,\epsilon^{ad}}(\epsilon^{-al} - 1) \quad [17]$$

which is the mean temperature of the intake of the rise workings.

If $\alpha = 0$ this becomes

$$T_{2R}^{\alpha = o} = t + md + \frac{\left(t - \theta - \frac{m}{a}\right) + \frac{m}{a}\epsilon^{ad}}{al\,\epsilon^{ad}}(\epsilon^{-al} - 1) \ldots\ldots [18]$$

and if $\theta = t$

$$T_{2R}^{\left\{\begin{matrix}\alpha = o \\ \theta = t\end{matrix}\right.} = t + md + \frac{m(\epsilon^{ad} - 1)(\epsilon^{-al} - 1)}{a^2 l\,\epsilon^{ad}} \ldots\ldots\ldots\ldots [19]$$

RISE WORKINGS RETURN AIR COURSE.

(17.)—Take z any variable distance from the end of the intake, and β the angle of inclination, which will now be negative

θ''' = temperature lost or gained at z.

Temperature of earth at z = temperature at end of intake + $m\,z$ sin. β because β is negative.

$$= t + m(d - l \sin.\alpha) + m\,z \sin.\beta$$

Temperature of air at $z = T_{2R} + \theta'''$

therefore

$$d\,\theta''' = a\,\{t + m(d - l \sin.\alpha) + m\,z \sin.\beta - (T_{2R} + \theta''')\}\,dz$$

$$d\,\theta''' + a\,\theta'''\,dz = a\,\{t + m(d - l \sin.\alpha) - T_{2R}\}\,dz + a\,m \sin.\beta\,z\,dz$$

and integrating

$$\theta''' e^{az} = a\{t - T_{2R} + md - ml\sin\alpha\}\frac{e^{az}}{a} + am\sin\beta\left\{\frac{e^{az}}{a}z - \frac{e^{az}}{a^2}\right\} + C$$

and since $\theta''' = 0$ when $z = 0$

$$0 = a\{t - T_{2R} + md - ml\sin\alpha\}\frac{1}{a} + 0 - \frac{m\sin\beta}{a} + C$$

whence, by subtracting

$$\theta''' e^{az} = (t - T_{2R} + md - ml\sin\alpha)(e^{az} - 1) + m\sin\beta\left(e^{az}z - \frac{e^{az}}{a} + \frac{1}{a}\right)$$

$$\theta''' = (t - T_{2R} + md - ml\sin\alpha)\left(1 - \frac{1}{e^{az}}\right) + m\sin\beta z - \frac{m\sin\beta}{a}\left(1 - \frac{1}{e^{az}}\right)$$

$$\theta''' = \left(t - T_{2R} + md - ml\sin\alpha - \frac{m\sin\beta}{a}\right)\left(1 - \frac{1}{e^{az}}\right) + m\sin\beta z \ldots [20]$$

which is the equation giving the variation in temperature at any part z of the return workings.

when $z = l'$ this becomes

$$\theta'''_{z=l'} = \left(t - T_{2R} + md - ml\sin\alpha - \frac{m}{a}\sin\beta\right)\left(1 - \frac{1}{e^{al'}}\right) + m\sin\beta l' \ldots [21]$$

and the temperature at the end of the return air course becomes

$$T_{2R} = T_{2R} + \theta'''_{z=l'} = T_{2R} + \left(t - T_{2R} md - ml\sin\alpha - \frac{m}{a}\sin\beta\left(1 - \frac{1}{e^{al'}}\right) + m\sin\beta l'\right.$$

$$= t + md - m(l\sin\alpha - l'\sin\beta) - \frac{m}{a}\sin\beta - \frac{t - T_{2R} + md - ml\sin\alpha - \frac{m}{a}\sin\beta}{e^{al'}} \quad [22]$$

and replacing T_{2R} by its value

$$_{R} = t + md - m(l\sin\alpha - l'\sin\beta) - \frac{m}{a}\sin\beta - \frac{\left(t - \theta - \frac{m}{a}\right) - \frac{m}{a}(\sin\beta + \sin\alpha)e^{al + ad} + \frac{m}{a}(\sin\alpha + 1)e^{ad}}{e^{al' + al + ad}} \quad [2$$

If $\alpha = \beta$ and $l = l'$ or the returns descend to the same point as the intake commences from, this becomes

$$T_{2R}^{\begin{cases}\alpha=\beta\\ l=l'\end{cases}} = t + md - \frac{m}{a}\sin\alpha - \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin\alpha + 1)e^{ad} - \frac{m}{a}(2\sin\alpha)e^{al + ad}}{e^{2al + ad}} \quad [24]$$

and if $\alpha = 0$ this becomes

$$T_{2R}^{\alpha=0} = t + md - \frac{t - \theta - \frac{m}{a} + \frac{m}{a}e^{ad}}{e^{2al + ad}}$$

$$= t + md - \frac{t - \theta + \frac{m}{a}(e^{ad} - 1)}{e^{2al + ad}} \ldots\ldots\ldots [25]$$

and if $t = 0$

$$T_{2R}\begin{cases}a=0\\ t=s\end{cases} = t + m\,d - \frac{\frac{m}{a}(\epsilon^{a\,d}-1)}{\epsilon^{2a\,l\,+\,a\,d}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [26]$$

(18.)—Mean temperature of return air-course rise workings,

$$T_{2R} = T_{2R} + \frac{1}{l'}\int \theta''' \, d\,z$$

and since $\theta''' = (t - T_{2R} + m\,d - m\,l\sin\alpha - \frac{m}{a}\sin\beta)(1 - \frac{1}{\epsilon^{a\,z}}) + m\sin\beta z$

$$\text{or} = N' - N'\,\epsilon^{-az} + m\sin a\,z$$

$$T_{2R} = T_{1R} + \frac{1}{l'}\int (N'\,d\,z - N'\,\epsilon^{-az}\,d\,z + m\sin\beta\,z\,d\,z)$$

and integrating and making $z = l'$

$$T_{2R} = T_{1R} + N' + \frac{N'}{a\,l'}(\epsilon^{-\,a\,l'} - 1) + \frac{m}{2}\sin\beta\,l'$$

and replacing N′ by its value,

$$T_{sR}=T_{sR}+t-T_{sR}+md-ml\sin\alpha-\frac{m}{a}\sin\beta+\frac{t-T_{sR}+md-ml\sin\alpha-\frac{m}{a}\sin\beta}{al'}(e^{-al'}-1)+\frac{m}{2}\sin\beta l'$$

$$=t+md-ml\sin\alpha-\frac{m}{a}\sin\beta+\frac{(t-T_{sR}+md-ml\sin\alpha-\frac{m}{a}\sin\beta)}{al'}(e^{-al'}-1)+\frac{m}{2}\sin\beta l' \quad\ldots\ldots[27]$$

or

$$T_{sR}=t+md-ml\sin\alpha-\frac{m}{a}\sin\beta+\frac{m}{2}\sin\beta l'+\frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+1)e^{ad}-\frac{m}{a}(\sin\alpha+\sin\beta)e^{al+ad}}{al'e^{al+ad}}(e^{-al'}-1) \quad\ldots\ldots[28]$$

which is the mean temperature of the return air-course.

If now $\alpha=\beta$ and $l'=l$, this becomes

$$T_{sR}\begin{cases}\alpha=\beta\\ l=l'\end{cases}=t+md-\frac{m}{2}l\sin\alpha-\frac{m}{a}\sin\alpha+\frac{\left(t-\theta-\frac{m}{a}\right)+\frac{m}{a}(\sin\alpha+1)e^{ad}-\left(\frac{m}{a}2\sin\alpha\right)e^{al+ad}}{ale^{al+a}}(e^{-al}-1) \quad\ldots\ldots[29]$$

and if $a = 0$,

$$T_{sR}^{a=0} = t + m\,d + \frac{t - \theta + \frac{m}{a}(\epsilon^{ad} - 1)}{a\,l\,\epsilon^{al+ad}}(\epsilon^{-al} - 1) \quad \ldots\ldots [30]$$

and if $t = \theta$,

$$T_{sR}^{\left\{\begin{smallmatrix} a=0 \\ t=0 \end{smallmatrix}\right.} = t + m\,d + \frac{m}{a^2 l}\frac{(\epsilon^{ad} - 1)(\epsilon^{-al} - 1)}{\epsilon^{al+ad}} \quad \ldots\ldots\ldots\ldots [31]$$

UPCAST SHAFT FROM RISE WORKINGS.

(19.)—Let θ''' be the alteration of temperature in passing up to any point x', then

$$T_{sR} + \theta''' = \text{temperature of air at } x'$$

but $t + m\,d - m\,x' = t + m\,(d - x') = $ temperature of the earth at x

$\therefore$ difference of temperature $= t + m\,(d - x') - (T_{sR} + \theta''')$

and therefore

$$d\,\theta''' = a'\,(t + m\,(d - x') - (T_{sR} + \theta'''))\,d\,x'$$

whence we get

$$d\,\theta''' + a\,\theta'''\,d\,x' = a'\,(t - T_{sR} + m\,d)\,d\,x' - a'\,m\,x'\,d\,x'$$

from which we obtain by integrating as before

$$\theta''' = \left(t - T_{sR} + m\,d + \frac{m}{a'}\right)\left(1 - \epsilon^{-a'x'}\right) - m\,x' \ldots\ldots \ldots [32]$$

which, when $x' = d'$, becomes

$$\theta_R''' = \left(t - T_{sR} + m\,d + \frac{m}{a'}\right)\left(1 - \epsilon^{-a'd'}\right) - m\,d' \ldots\ldots\ldots [33]$$

which is the temperature lost or gained in the upcast shaft,

and putting for T_s its value T_{sR} from [24]

and reducing, we get temperature at top of upcast shaft, or

$$T_{tR} = T_{sR} + t - T_{sR} + m\,d + \frac{m}{a'} - m\,d' - \frac{t - T_{sR} + m\,d + \frac{m}{a'}}{\epsilon^{a'd'}}$$

$$= t + m\,(d - d') + \frac{m}{a'} - \frac{t - T_{sR} + m\,d + \frac{m}{a'}}{\epsilon^{a'd'}} \ldots\ldots\ldots [34]$$

and replacing T_{sR} by its value [23], and reducing

$$T_{4R} \quad t + m(d - d') + \frac{m}{a'} - \frac{\left(t - \theta - \frac{m}{a}\right) + \frac{m}{a}\left(\sin\alpha + 1\right)e^{ad} - \frac{m}{a}\left(\sin\alpha + \sin\beta\right)e^{al + ad}}{e^{al' + al + ad}} + \frac{m}{a'} + \frac{m}{a}\sin\beta + m(l\sin\alpha - l'\sin\beta}{e^{a'd'}} \quad \ldots [35]$$

If $a' = a$ this becomes

$$T_{4R}^{a'=a} = t + m(d - d') + \frac{m}{a} - \frac{\frac{m}{a}(\sin\beta + 1) + m(l\sin\alpha - l'\sin\beta) + t - \theta - \frac{m}{a} - \frac{m}{a}(\sin\alpha + \sin\beta)e^{a + ad} + \frac{m}{a}(\sin\alpha + 1)e^{ad}}{e^{al' + al + ad}} \quad [36]$$

If $d = d'$ or the shafts are the same depth

$$T_{4R}^{d'=d} = t + \frac{m}{a} - \frac{\left\{\frac{m}{a}(\sin\beta + 1) + m(l\sin\alpha - l'\sin\beta)\right\}e^{a' + al + ad} + t - \theta - \frac{m}{a} - \frac{m}{a}\left(\sin\alpha + \sin\beta\right)e^{al + ad} + \frac{m}{a}(\sin\alpha + 1)e^{ad}}{e^{al' + al + 2ad}} \quad \ldots [37]$$

If $\alpha = \beta$ and $l = l'$

$$T_{4R}^{\substack{\alpha=\beta \\ l=l' \\ d=d'}} = t + \frac{m}{a} - \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin\alpha + 1)(e^{2al + ad} + e^{ad}) - \frac{m}{a}2\sin\alpha e^{al + ad}}{e^{2al + 2ad}} \quad \ldots [38]$$

If $a = 0$

$$T_{4R}^{\begin{cases} a=0 \\ l=l' \\ d=d' \end{cases}} = t + \frac{m}{a} - \frac{t - \theta - \frac{m}{a} + \frac{m}{a}\left(\epsilon^{2al + ad} + \epsilon^{ad}\right)}{\epsilon^{2al + 2ad}} \quad \ldots\ldots\ldots [39]$$

If $t = \theta$

$$T_{4R}^{\begin{cases} a=0 \\ \theta=t \end{cases}} = t + \frac{m}{a} - \frac{\frac{m}{a}\left\{\epsilon^{ad}(\epsilon^{2al} + 1) - 1\right\}}{\epsilon^{2al+2ad}} \quad \ldots\ldots\ldots\ldots [40]$$

(20.)—Mean temperature of upcast shaft.

$$T_{4R} = T_{3R} + \frac{1}{d'}\int^{x'=d'} \theta''' \, dx'$$

$$= T_{3R} + \frac{1}{d'}\int^{x'=d'} \left\{\left(t - T_3 + m\,d + \frac{m}{a'}\right)\left(1 - \epsilon^{-a'x'}\right) - m\,x'\right\} dx'$$

and writing $t - T_3 + m\,d + \frac{m}{a'} = N$

$$T_{4R} = T_{3R} \frac{1}{d'}\left\{\int N\,dx' - N\int \epsilon^{-a'x'}\,dx - m\int x'\,dx'\right\}$$

and integrating the part within the brackets it becomes, making $x' = d'$,

$$T_{4R} = T_{3R} + N + \frac{N}{a'd'}(\epsilon^{-a'd'} - 1) - \frac{m}{2}d'$$

and replacing N by its value

$$T_{4R} = T_{3R} + t - T_{3R} + md + \frac{m}{a'} + \frac{t - T_{3P} + md + \frac{m}{a'}}{a'd'}(\epsilon^{-a'd'} - 1) - \frac{m}{2}d'$$

$$= t + md + \frac{m}{a'} - \frac{m}{2}d' + \frac{t - T_{3R} + md + \frac{m}{a'}}{a'd'}(\epsilon^{-a'd'} - 1) \quad \ldots\ldots [41]$$

and replacing T_{3R} by its value [23]

$$T_{4R} = t + md + \frac{m}{a'} - \frac{m}{2}d' + \frac{\left\{\frac{m}{a'} + \frac{m}{a}\sin\beta + m\,(l\sin\alpha - l'\sin\beta)\right\} e^{al'+al+ad} + t - \theta - \frac{m}{a} - \frac{m}{a}(\sin\beta+\sin\alpha)\,e^{al+ad} + \frac{m}{a}(\sin\alpha+1)\,e^{ad}}{a'\,d'\,e^{al'+al+ad}}(e^{-ad'}-1) \quad [42]$$

which, when $a' = a$, becomes

$$T_{4R}^{a'=a} = t + md + \frac{m}{a} - \frac{m}{2}d' + \frac{\left\{\frac{m}{a}(\sin\beta+1) + m(l\sin\alpha + l'\sin\beta)\right\} e^{al'+al+ad} t - \theta - \frac{m}{a} - \frac{m}{a}(\sin\beta+\sin\alpha)\,e^{al+ad} + \frac{m}{a}(\sin\alpha+1)\,e^{ad}}{a\,d'\,e^{al'+al+ad}}(e^{-ad'}-1) \quad [43]$$

and when $d = d'$

$$T_{4R}^{\begin{cases} d=d' \\ a=a' \end{cases}} = t + \frac{m}{2}d + \frac{m}{a} + \frac{\left\{\frac{m}{a}(\sin\beta+1) + m(l\sin\alpha - l'\sin\beta)\right\} e^{al'+al+ad} + t - \theta - \frac{m}{a} - \frac{m}{a}(\sin\beta+\sin\alpha)e^{al+ad} + \frac{m}{a}(\sin\alpha+1)\,e^{ad}}{a\,d\,e^{al'+al+ad}}(e^{-ad}-1) \quad [44]$$

If $\alpha = \beta$ and $l = l'$

$$T_{4R}^{\begin{cases} \alpha=\beta \\ l=l' \end{cases}} = t + \frac{m}{2}d + \frac{m}{a} + \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin\alpha+1)(e^{2al+ad}+e)^{ad} - \frac{m}{a}(2\sin\alpha)e^{al+ad}}{a\,d\,e^{2al+ad}}(e^{-ad}-1) \quad [45]$$

And when $\alpha = 0$

$$T_{4R}^{\alpha=0} = t + \frac{m}{2}d + \frac{m}{a} + \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(e^{2al+ad}+e^{ad})}{a\,d\,e^{2al+ad}}(e^{-ad}-1) \quad [46]$$

If $\theta = t$

$$T_{4R}^{\begin{cases} \alpha=0 \\ \theta=t \end{cases}} = t + \frac{m}{2}d + \frac{m}{a} + \frac{m\,(e^{2al+ad} + e^{ad} - 1)}{a^2\,d\,e^{2al+ad}}(e^{-ad}-1) \quad [47]$$

(21.)—We have now obtained a complete set of expressions for the final and mean temperatures of the shafts and *rise* workings, and we might, in like manner, proceed to deduce expressions for the mean and final temperatures of the shafts and *dip* workings, but we may arrive at these at once by observing that the only difference in this case from the last is in the direction of the angle, which will now be positive, where before it was negative, and *vice versa*, so that by reversing the signs of the terms involving $\sin \alpha$ and $\sin \beta$ we get the expressions for the dip workings.

The final and mean temperatures and the equation of temperature for the downcast shaft will of course remain unaltered, and therefore we need not repeat them.

(22.)—For the intake of the dip workings we shall have

Equation of temperature or

$$\theta'' = t - T_1 + m d - \frac{m \sin \alpha}{a}\left(1 - \frac{1}{\epsilon^{a y}}\right) + m \sin \alpha \, y \quad \ldots\ldots\ldots [48]$$

which when $y = l$ becomes

$$\theta''^{y=l} = t - T_1 + m d - \frac{m \sin \alpha}{a}\left(1 - \frac{1}{\epsilon^{a l}}\right) + m \sin \alpha \, l \quad \ldots\ldots [49]$$

(23.)—Final temperature at end of intake

$$T_{2D} = t + md - \frac{m}{a}\sin\alpha + ml\sin\alpha - \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(1 - \sin\alpha)\epsilon^{ad}}{\epsilon^{al+ad}} \quad \ldots\ldots [50]$$

when $\alpha = 0$

$$T_{2D}{}^{\alpha=0} = t + m d - \frac{t - \theta + \frac{m}{a}(\epsilon^{ad} - 1)}{\epsilon^{al+ad}} \quad \ldots\ldots\ldots\ldots [51]$$

when $\theta = t$

$$T_{2D}{}^{\begin{cases}\alpha = 0 \\ \theta = t\end{cases}} = t + m d - \frac{m}{a}\frac{\epsilon^{ad} - 1}{\epsilon^{al+ad}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [52]$$

(24.)—Mean temperature of intake dip workings

$$T_{2D} = t + md + \frac{m}{2}l\sin\alpha - \frac{m}{a}\sin\alpha + \frac{\left(t - \theta - \frac{m}{a}\right) + \frac{m}{a}\left(1 - \sin\alpha\right)\epsilon^{ad}}{al\epsilon^{ad}}\left(\epsilon^{-al} - 1\right) [53]$$

when $\alpha = o$

$$T_{2D}^{\alpha=o} = t + m d + \frac{\left(t - \theta - \frac{m}{a}\right) + \frac{m}{a} e^{ad}}{a\, l\, e^{ad}} (e^{-al} - 1) \ldots [54]$$

and if $\theta = t$

$$T_{2D}^{\substack{\alpha=0 \\ \theta=t}} = t + m d + \frac{m (e^{ad} - 1)(e^{-al} - 1)}{a^2\, l\, e^{ad}} \ldots\ldots\ldots\ldots\ldots [55]$$

(25).—Return air-course dip workings.

Equation of temperature

$$\theta'' = \left(t - T_{2D} + m d + m l \sin \alpha + \frac{m}{a} \sin \beta\right)\left(1 - \frac{1}{e^{az}}\right) - m \sin \beta z [56]$$

and when $z = l'$

$$\theta''^{z=l'} = \left(t - T_{2D} + md + ml \sin\alpha + \frac{m}{a} \sin \beta\right)\left(1 - e^{-al'}\right) - m \sin \beta l' [57]$$

(26.)—Temperature at end of return air-course Dip workings.

$$T_{sD} = t + m\,d + m(l\sin\alpha - l'\sin\beta) + \frac{m}{a}\sin\beta - \frac{t-\theta-\frac{m}{a}+\frac{m}{a}\left(\sin\beta+\sin\alpha\right)\epsilon^{a\,l+a\,d}+\frac{m}{a}\left(1-\sin\alpha\right)\epsilon^{a\,d}}{\epsilon^{a\,l'+a\,l+a\,d}} \quad \ldots\ldots [58]$$

If $\alpha = \beta$ and $l' = l$

$$T_{s\,D}^{\begin{cases}\alpha=\beta\\ l=l'\end{cases}} = t + m\,d + \frac{m}{a}\sin\alpha - \frac{t-\theta-\frac{m}{a}+\frac{m}{a}\left(1-\sin\alpha\right)\epsilon^{a\,d}+\frac{m}{a}\left(2\sin\alpha\right)\epsilon^{a\,l+a\,d}}{\epsilon^{2\,a\,l+a\,d}} \quad \ldots\ldots [59]$$

If $\alpha = 0$

$$T_{s\,D}^{\alpha=0} = t + m\,d - \frac{t-\theta-\frac{m}{a}+\frac{m}{a}\,\epsilon^{a\,d}}{\epsilon^{2\,a\,l+a\,d}} = t + m\,d - \frac{t-\theta+\frac{m}{a}\,(\epsilon^{a\,d}-1)}{\epsilon^{2\,a\,l+a\,d}} \quad \ldots\ldots [60]$$

If $\theta = t$

$$T_{s\,D}^{\begin{cases}\alpha=0\\ \theta=t\end{cases}} = t + m\,d - \frac{m(\epsilon^{a\,d}-1)}{a\,\epsilon^{2\,a\,l+a\,d}} \quad \ldots\ldots [61]$$

(27.)—Mean temperature of return air-course Dip workings.

$$T_{s\,D} = t + m\,d + m\,l\sin\alpha + \frac{m}{a}\sin\beta - \frac{m}{2}\sin\beta l' + \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(1-\sin\alpha)\,\epsilon^{a\,d}+\frac{m}{a}\,(\sin\alpha+\sin\beta)\,\epsilon^{a\,l+a\,d}}{a\,l'\,\epsilon^{a\,l+a\,d}}(\epsilon^{-a\,l'}-1) \quad [62]$$

If $\alpha = \beta$ and $l = l'$

$$T_{s\,D}^{\begin{cases}\alpha=\beta\\ l=l'\end{cases}} = t + m\,d + \frac{m}{2}\sin\alpha\,l + \frac{m}{a}\sin\alpha + \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(1-\sin\alpha)\,\epsilon^{a\,d}+\frac{m}{a}(2\sin\alpha)\,\epsilon^{a\,l+a\,d}}{a\,l\,\epsilon^{a\,l+a\,d}}(\epsilon^{-a\,l}-1) \quad \ldots\ldots [63]$$

If $a = 0$

$$T_{s\,D}^{a=0} = t + m\,d + \frac{t - \theta + \frac{m}{a}(e^{a\,d} - 1)}{a\,l\,e^{a\,l + a\,d}}(e^{-a\,l} - 1) \quad \ldots\ldots\ldots\ldots \quad [64]$$

And if $\theta = t$

$$T_{s\,D}^{\begin{cases} a=0 \\ \theta=t \end{cases}} = t + m\,d + \frac{m\,(e^{a\,d} - 1)\,(e^{-a\,l} - 1)}{a^2\,l\,e^{a\,l + a\,d}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad [65]$$

(28.)—Upcast shaft for dip workings.

Equation of temperature

$$\theta_{D}^{''''} = \left(t - T_{s\,D} + m\,d + \frac{m}{a'}\right)\left(1 - e^{-a'\,x'}\right) - m\,x' \ldots\ldots\ldots \quad [66]$$

which, when $x' = d'$, becomes

$$\theta_{B}^{''''\,x' = d'} = \left(t - T_{s\,D} + m\,d + \frac{m}{a'}\right)\left(1 - e^{-a'\,d'}\right) - m\,d' \ldots\ldots \quad [67]$$

(29.)—Final temperature of upcast shaft dip workings.

$$T_{4D}=t+m(d-d')+\frac{m}{a'}-\frac{\frac{m}{a'}-\frac{m}{a}\sin\beta-m(l\sin\alpha-l'\sin\beta)+\frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+\sin\beta)\epsilon^{al+ad}+\frac{m}{a}(1-\sin\alpha)\epsilon^{ad}}{\epsilon^{al'+al+ad}}}{\epsilon^{a'd'}} \quad \ldots\ldots\ldots\ldots [68]$$

If $a'=a$ this becomes

$$T_{4D}{}^{a=a'}=t+m(d-d')+\frac{m}{a}-\frac{\frac{m}{a}(1-\sin\beta)-m(l\sin\alpha-l'\sin\beta)+\frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+\sin\beta)\epsilon^{al+ad}+\frac{m}{a}(1-\sin\alpha)\epsilon^{ad}}{\epsilon^{al'+al+ad}}}{\epsilon^{ad'}} \quad \ldots\ldots [69]$$

If $d=d'$ or the shafts are the same depth,

$$T_{4D}{}^{d=d'}=t+\frac{m}{a}-\frac{\left\{\frac{m}{a}(1-\sin\beta)-m(l\sin\alpha-l'\sin\beta)\right\}\epsilon^{al'+al+ad}+t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+\sin\beta)\epsilon^{al+ad}+\frac{m}{a}(1-\sin\alpha)\epsilon^{al}}{\epsilon^{al'+al+2ad}} \quad \ldots [70]$$

If $\alpha=\beta$

$$T_{4D}{}^{\begin{cases}d=d'\\ \alpha=\beta\\ l=l'\end{cases}}=t+\frac{m}{a}-\frac{t-\theta-\frac{m}{a}+\frac{m}{a}(1-\sin\alpha)(\epsilon^{2al+ad}+\epsilon^{ad})+\frac{m}{a}(2\sin\alpha)\epsilon^{al+ad}}{\epsilon^{2al+2ad}} \quad \ldots\ldots\ldots\ldots [71]$$

If $\alpha=0$

$$T_{4D}{}^{\alpha=0}=t+\frac{m}{a}-\frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\epsilon^{2al+ad}+\epsilon^{ad})}{\epsilon^{2al+2ad}} \quad \ldots\ldots\ldots\ldots [72]$$

If $\theta=t$

$$T_{4D}{}^{\begin{cases}\alpha=0\\ \theta=t\end{cases}}=t+\frac{m}{a}-\frac{\frac{m}{a}(\epsilon^{2al+ad}+\epsilon^{ad}-1)}{\epsilon^{2al+2ad}} \quad \ldots\ldots\ldots\ldots [73]$$

(30.)—Mean temperature of upcast shaft Dip workings.

$$T_{4D} = t + md + \frac{m}{a'} - \frac{m}{2}d' + \frac{\left\{\frac{m}{a'} - \frac{m}{a}\sin\beta - m(l\sin\alpha - l'\sin\beta)\right\}\epsilon^{al'+al+ad} + t - \theta - \frac{m}{a} + \frac{m}{a}(\sin\beta + \sin\alpha)\epsilon^{al+ad} + \frac{m}{a}(1-\sin\alpha)\epsilon^{ad}}{a'd'\epsilon^{al'+al+ad}}(\epsilon^{-a'd'}-1) \quad \ldots\ldots\ldots [74]$$

which, when $a' = a$, becomes

$$T_{4D}^{a'=a} = t + md + \frac{m}{a} - \frac{m}{2}d' + \frac{\left\{\frac{m}{a}(1-\sin\beta) - m(l\sin\alpha - l'\sin\beta)\right\}\epsilon^{al'+al+ad} + t - \theta - \frac{m}{a} + \frac{m}{a}(\sin\beta + \sin\alpha)\epsilon^{al+ad} + \frac{m}{a}(1-\sin\alpha)\epsilon^{ad}}{ad'\epsilon^{al'+al+a}}(\epsilon^{-ad'}-1) \ldots [75]$$

and when $d = d'$

$$T_{4D}^{d=d'} = t + \frac{m}{2}d + \frac{m}{a} + \frac{\left\{\frac{m}{a}(1-\sin\beta) - m(l\sin\alpha - l'\sin\beta)\right\}\epsilon^{al'+al+ad} + t - \theta - \frac{m}{a} + \frac{m}{a}(\sin\beta + \sin\alpha)\epsilon^{al+ad} + \frac{m}{a}(1-\sin\alpha)\epsilon^{ad}}{ad\epsilon^{al'+al+ad}}(\epsilon^{-ad}-1) \ldots\ldots [76]$$

If $\alpha = \beta$

$$T_{4D}^{\substack{d=d' \\ \alpha=\beta}} = t + \frac{m}{2}d + \frac{m}{a} + \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(1-\sin\alpha)(\epsilon^{2al+ad} + \epsilon^{ad}) + \frac{m}{a}(2\sin\alpha)\epsilon^{al+ad}}{ad\epsilon^{2al+ad}}(\epsilon^{-ad}-1) \quad \ldots\ldots\ldots\ldots\ldots [77]$$

And when $\alpha = 0$

$$T_{4D}^{\alpha=0} = t + \frac{m}{2}d + \frac{m}{a} + \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\epsilon^{2al+ad} + \epsilon^{ad})}{ad\epsilon^{2al+ad}}(\epsilon^{-a}-1) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [78]$$

And if $\theta = t$

$$T_{4D}^{\substack{\alpha=0 \\ \theta=t}} = t + \frac{m}{2}d + \frac{m}{a} + \frac{m(\epsilon^{2al+ad} + \epsilon^{ad} - 1)}{a^2d\epsilon^{2al+ad}}(\epsilon^{-ad}-1) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [79]$$

It will be observed that the expressions for the rise and dip workings become identical when we make $\alpha = 0$, which, of course, they ought to do, since they are then exactly similarly situated as regards the temperature of the earth.

In the case of the upcast shaft we have thought it best to introduce into the formula a different constant, a' from that a used in the other cases, as it will appear hereafter that owing to peculiar circumstances, probably from excess of water in the upcast shaft or from the effect of increased evaporation due to the increased temperature, the same constant may not apply.

Nevertheless, in the consideration of the question abstractedly as one of temperature lost to or gained from the earth, and apart from other influences, there can be no reason why the same constant should not apply, and we have, therefore, afterwards exhibited the formula, supposing a' to become a.

(31.)—In the above investigation the workings are supposed to proceed in straight drifts with a uniform angle to the rise and dip respectively, but the same formula will apply to the ordinary case of board and pillar workings through which the air is coursed, by using $\frac{h}{l}$ instead of $\sin \alpha$ where h is the extreme vertical rise or fall and l the length of the workings.

(32.)—These equations may be made more general in form by supposing the angle of inclination simply to vary, instead of to become negative at the end of the intake of the rise workings. We can then, by giving their proper values and signs to the angles, make the formula to suit any series of workings. For this purpose we have only to substitute α_2 for β, and x_2 for z, reversing the signs in equation [20] and those deduced from it, and we get

$$\theta''' = (t - T_{2R} + m\,d - m\,l \sin \alpha_1 + \frac{m}{a} \sin \alpha_2)\left(1 - \frac{1}{e^{a x_2}}\right) - m \sin \alpha_2\, x_2 \quad \text{[80]}$$

and if $x_2 = l_2$

$$\theta'''_{x_2 = l_2} = \left(t - T_{2R} + m\,d - m\,l \sin \alpha_1 + \frac{m}{a} \sin \alpha_2\right)\left(1 - \frac{1}{e^{a l_2}}\right) - m \sin \alpha_2\, l_2 \quad \text{[81]}$$

therefore, final temperature at end of l_2, or

$$T_3 = t + m\,d - m\,(l_1 \sin \alpha_1 + l_2 \sin \alpha_2) + \frac{m}{a} \sin \alpha_2 - \frac{t - T_{2R} + m\,d - m\,l_1 \sin \alpha_1 + \frac{m}{a} \sin \alpha_2}{e^{a l_2}} \quad \text{[82]}$$

$$= t + m\,d - m\,(l_1 \sin \alpha_1 + l_2 \sin \alpha_2) + \frac{m}{a} \sin \alpha_2 - \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin \alpha_1 + 1) e^{a d} - \frac{m}{a}(\sin \alpha_1 - \sin \alpha_2)\, e^{a l_1 + a d}}{e^{a l_2 + a l_1 + a d}} \quad \text{[83]}$$

and mean temperature in l_2, or

$$T_3 = t + m\,d - m\,l_1 \sin \alpha_1 + \frac{m}{a} \sin \alpha_2 - \frac{m}{2} \sin \alpha_2\, l_2 + \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin \alpha_1 + 1) e^{a d} - \frac{m}{a}(\sin \alpha_1 - \sin \alpha_2)\, e^{a l_1 + a d}}{a\, l_2\, e^{a l_2 + a l_1 + a d}} (e^{-a l_2} - 1) \quad \text{[84]}$$

again,

$$\theta'''' = \left(t - T_{2R} + m\,d - m\,(l_1 \sin \alpha_1 + l_2 \sin \alpha_2) + \frac{m}{a} \sin \alpha_2\right)\left(1 - \frac{1}{e^{a x_2}}\right) - m \sin \alpha_2\, x_2 . \quad \text{[85]}$$

And, when $x_3 = l_3$,

$$\theta''_{x_3=l_3} = \left\{t - T_{3R} + m\,d - m\,(l_1 \sin\alpha_1 + l_2 \sin\alpha_2) + \frac{m}{a}\sin\alpha_3\right\}\left(1 - \frac{1}{\epsilon^{a l_3}}\right) - m \sin\alpha_3 l_3 \quad \text{[86]}$$

Whence, final temperature at end of l_3, or

$$T_4 = t + m\,d - m\,(l_1 \sin\alpha_1 + l_2 \sin\alpha_2 + l_3 \sin\alpha_3) + \frac{m}{a}\sin\alpha_3 - \frac{t - T_{3R} + m\,d - m\,(l_1 \sin\alpha_1 + l_2 \sin\alpha_2) + \frac{m}{a}\sin\alpha_3}{\epsilon^{a l_3}} \quad \text{[87]}$$

$$= t + m\,d - m(l_1 \sin\alpha_1 + l_2 \sin\alpha_2 + l_3 \sin\alpha_3) + \frac{m}{a}\sin\alpha_3 - \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin\alpha_1 + 1)\epsilon^{ad} - \frac{m}{a}(\sin\alpha_1 - \sin\alpha_2)\epsilon^{al_1 + ad} - \frac{m}{a}(\sin\alpha_2 - \sin\alpha_3)\epsilon^{al_2 + al_1 + ad}}{\epsilon^{a l_3 + a l_2 + a l_1 + ad}} \quad \text{[88]}$$

And mean temperature in l_3

$$T_{3R} = t + md - m(l_1 \sin\alpha_1 + l_2 \sin\alpha_2) + \frac{m}{a}\sin\alpha_3 - \frac{m}{2}\sin\alpha_3 l_3 + \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin\alpha_1 + 1)\epsilon^{ad} - \frac{m}{a}(\sin\alpha_1 - \sin\alpha_2)\epsilon^{al_1 + ad} - \frac{m}{a}(\sin\alpha_2 - \sin\alpha_3)\epsilon^{al_2 + al_1 + ad}}{a l_3\, \epsilon^{a l_3 + a l_2 + a l_1 + ad}}(\epsilon^{-al_3} - 1) \quad \text{[89]}$$

Also, we have

Final temperature at end of the nth change of inclination

$$T_{nR} = t + md - m(\mathbf{LS}_{n-1}) + \frac{m}{a}\sin\alpha_n - \frac{\mathbf{N} + \frac{m}{a}(\sin\alpha_1 + 1)\epsilon^{ad} - \frac{m}{a}(\Delta\mathbf{S}^{n-2}_{n-1})\epsilon^{a(\mathbf{L}_{n-2} + d)}}{\epsilon^{a(\mathbf{L}_{n-2} + d)}} \quad \text{[90]}$$

In which expression

$$\mathbf{N} = t - \theta - \frac{m}{a}$$

$$(\mathbf{L}\,\mathbf{S}_{n-1}) = l_1 \sin a_1 + l_2 \sin a_2 + \&c. \ldots\ldots\ldots\ldots + l_{n-1} \sin a_{n-1}$$

$$(\Delta\,\mathbf{S}^{n-2}_{n-1})e^{a(l_{n-1}+d)} = (\sin a_1 - \sin a_2)e^{a(l_1+d)} + (\sin a_2 - \sin a_3)e^{a(l_2+l_1+d)} + \&c.$$

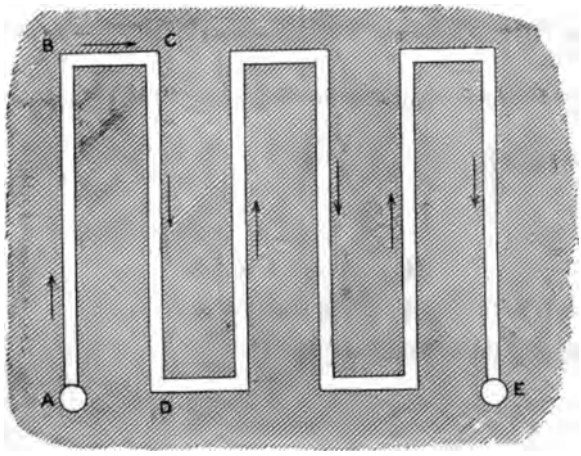
$$\ldots\ldots\ldots\ldots + (\sin a_{n-2} - \sin a_{n-1})\, e^{a(l_{n-2} + \&c. + l_1 + d)}$$

$$(\mathbf{L}_{n-2}) = l_{n-2} + l_{n-3} + \&c. \ldots\ldots\ldots + l_2 + l_1$$

$$(\mathbf{L}_{n-1}) = l_{n-1} + l_{n-2} + \&c. \ldots\ldots\ldots + l_2 + l_1$$

(34.)—As an example of the application of this, let us take a series of workings in which the air is carried to the full rise and back again to the dip several times successively, and if we call the distance apart between

Fig. 3.



each pair of ascending and descending air courses λ, and if A be the downcast shaft whose depth is d, E the upcast shaft

$$\text{A B} = l_1 = l$$

$$\text{B C} = l_2 = \lambda$$

the angle of inclination of A B which is to the full rise $= a$, and let the number of changes of inclination, or $n = 15$,

then we have

$$\left.\begin{matrix} l_1 \\ l_3 \\ l_5 \\ l_7 \\ l_9 \\ l_{11} \\ l_{13} \\ l_{15} \end{matrix}\right\} = l \qquad \left.\begin{matrix} l_2 \\ l_4 \\ l_6 \\ l_8 \\ l_{10} \\ l_{12} \\ l_{14} \end{matrix}\right\} = \lambda \qquad \left.\begin{matrix} a_1 \\ a_5 \\ a_9 \\ a_{13} \end{matrix}\right\} = +\,a \qquad \left.\begin{matrix} a_3 \\ a_7 \\ a_{11} \\ a_{15} \end{matrix}\right\} = -\,a \qquad \left.\begin{matrix} a_2 \\ a_4 \\ a_6 \\ a_8 \\ a_{10} \\ a_{12} \\ a_{14} \end{matrix}\right\} = 0$$

also, since n is an odd number, $(\mathbf{L}\,\mathbf{S}_{n-1})$ consists of an even number of terms of which all those involving λ vanish, and the others which are all equal are alternately positive and negative, so that we get

$$m\,(\mathbf{L}\,\mathbf{S}_{n-1}) = 0$$

Also in the term $(\Delta\,\mathbf{S}^{n-2}_{n-1})$ we have $\sin\alpha_2$, $\sin\alpha_4$, $\sin\alpha_6$, $\sin\alpha_8$, $\sin\alpha_{10}$, $\sin\alpha_{12}$, $\sin\alpha_{14}$, each $= 0$, and $\sin\alpha_3$, $\sin\alpha_7$, $\sin\alpha_{11}$, $\sin\alpha_{15}$, each $= -\sin\alpha$,

so that $\frac{m}{a}(\Delta\,\mathbf{S}^{n-2}_{n-1})\,\epsilon^{a(\mathbf{L}_{n-2}+d)}$ becomes

$$\frac{m}{a}\Big\{\sin\alpha\,\epsilon^{a(l+d)} + \sin\alpha\,\epsilon^{a(\lambda+l+d)} - \sin\alpha\,\epsilon^{a(2l+\lambda+d)} - \sin\alpha\,\epsilon^{a(2l+2\lambda+d)}$$

$$+ \sin\alpha\,\epsilon^{a(3l+2\lambda+d)} + \sin\alpha\,\epsilon^{a(3l+3\lambda+d)} - \sin\alpha\,\epsilon^{a(4l+3\lambda+d)} - \sin\alpha\,\epsilon^{a(4l+4\lambda+d)}$$

$$+ \sin\alpha\,\epsilon^{a(5l+4\lambda+d)} + \sin\alpha\,\epsilon^{a(5l+5\lambda+d)} - \sin\alpha\,\epsilon^{a(6l+5\lambda+d)} - \sin\alpha\,\epsilon^{a(6l+6\lambda+d)}$$

$$+ \epsilon^{a(7l+6\lambda+d)}\Big\}$$

and

$$(\mathbf{L}_{n-1}) = 7\,l + 7\,\lambda$$

$$\mathbf{L}_{n-2} = 7\,l + 6\,\lambda$$

and substituting these values in [90]

$$T_n = t + md + \frac{m}{a}\sin\alpha - \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+1)\epsilon^{ad}-\frac{m}{a}\sin\alpha\left\{\epsilon^{a(l+d)}+\epsilon^{a(l+\lambda+d}+\epsilon^{a(2l+\theta\lambda+d}\right.}{}$$

If we make λ so small that it may be neglected in comparison with l and

$$T_n = t + md + \frac{m}{a}\sin\alpha - \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+1)\epsilon^{ad}-\frac{m}{a}\sin\alpha\left\{2\epsilon^{a(l+d)}-2\epsilon^{a(}\right.}{\epsilon^{a}}$$

If we make $\lambda = l$

$$T_n^{l=\lambda} = t + md + \frac{m}{a}\sin\alpha - \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+1)\epsilon^{ad}-\frac{m}{a}\sin\alpha\left\{\epsilon^{a(l+d)}+\epsilon^{a(2l+}\right.}{}$$

$$= t + md + \frac{m}{a}\sin\alpha - \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+1)\epsilon^{ad}}{\epsilon^{a(14l+d)}\cdot} + \frac{m}{a}\sin\alpha\left\{\frac{1}{\epsilon^{13l}}+\frac{1}{\epsilon^{12l}}-\frac{1}{\epsilon^{11l}}-\right.$$

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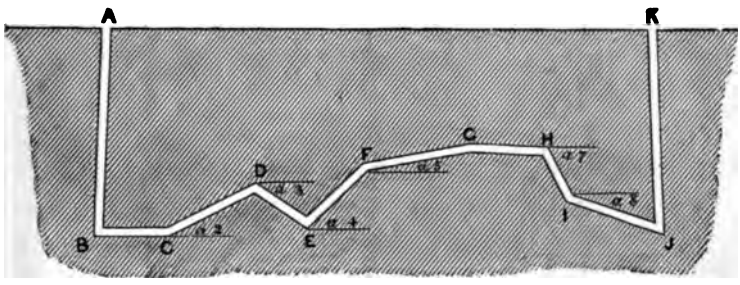
(35.)—The expression [90] is perfectly general, and will apply to any system of workings of any length and at any varying inclinations, it being borne in mind that in the notation l_m is the length of any portion of which a_m is the corresponding inclination, and that the first angle or a_1 is an angle to the rise, and considered positive. Should the first angle in the workings be to the dip, we have only to make $a_1 = 0$ and $l_1 = 0$ in the formula, and in cases of level portions make the angle belonging to the same $= 0$.

Fig. 4.



For instance, in the system represented in the sketch *Fig.* 4.

A B $= d$ the depth of the downcast shaft.
B C $= l_1$ its angle or $a_1 = 0$.
C D $= l_2$ its angle or a_2 positive.
D E $= l_3$ its angle or a_3 negative.
E F $= l_4$ its angle or a_4 positive.
F G $= l_5$ its angle or a_5 positive.
G H $= l_6$ its angle or $a_6 = 0$.
H I $= l_7$ its angle or a_7 negative.
I J $= l_8$ its angle or a_8 negative.
K J $= d_1$ the depth of the upcast shaft,

and so on with any number of rises and falls.

(36.)—We may now by means of the above formula compare the mean temperatures of the air in the upcast shaft coming from two sets of workings, one to the dip and the other to the rise, and as the simplest case shall take that represented by the diagrams, *Figs* 1 *and* 2, in which the workings start from the same level, proceed at the same angle the same distance to the dip and rise respectively, and return again to their original level at the bottom of the upcast shaft.

For this purpose we take by [77]

$$\text{Mean temperature of upcast Dip workings—} = t + \frac{m}{2}d + \frac{m}{a} + \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(1-\sin\alpha)(\epsilon^{2al+ad}+\epsilon^{ad})+\frac{m}{a}(2\sin\alpha)\epsilon^{al+ad}}{ad\epsilon^{2al+ad}}(\epsilon^{-ad}-1)$$

and, from [45],

$$\text{Mean temperature of upcast from Rise Workings.} = t + \frac{m}{2}d + \frac{m}{a} + \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+1)(\epsilon^{2al+ad}+\epsilon^{ad})-\frac{m}{a}(2\sin\alpha)\epsilon^{al+ad}}{ad\,\epsilon^{2al+ad}}\epsilon^{-ad}-1)$$

and subtracting the latter from the former, we get

$$\text{difference} = \frac{\epsilon^{-ad}-1}{ad\,\epsilon^{2al+ad}}\left\{\frac{m}{a}(1-\sin\alpha)(\epsilon^{2al+ad}+\epsilon^{ad})-\frac{m}{a}(\sin\alpha+1)(\epsilon^{2al+ad}+\epsilon^{ad})+\frac{m}{a}(4\sin\alpha)\epsilon^{al+ad}\right\}$$

$$= \frac{m}{a}(1-\epsilon^{ad}) \left\{ (\epsilon^{2al+ad} + \epsilon^{ad}) \times -2\sin a + 4\sin a\, \epsilon^{al+ad} \right\}$$
$$\overline{a\, d\, \epsilon^{2al+2ad}}$$

$$= \frac{m}{a^2 d}\ 2\sin a \frac{1-\epsilon^{ad}}{\epsilon^{al+ad}} \left\{ 2 - \{\epsilon^{al} + \epsilon^{-al}\} \right\}$$

$$= \frac{m}{a^2 d}\ 2\sin a \frac{1-\epsilon^{ad}}{\epsilon^{al+ad}} \left\{ 2 - \epsilon^{al} - \epsilon^{-al} \right\}$$

$$= \frac{m}{a^2 d}\ 2\sin a \frac{\epsilon^{ad}-1}{\epsilon^{al+ad}} \left\{ \epsilon^{al} + \epsilon^{-al} - 2 \right\}$$

$$= \frac{m}{a^2 d}\ 2\sin a \frac{(\epsilon^{ad}-1)(\epsilon^{2al} - 2\,\epsilon^{al} + 1)}{\epsilon^{2al+ad}}$$

which is the excess of the mean temperature of the upcast shaft from the dip workings over the mean temperature of the upcast from the rise workings, and consequently represents the excess of ventilating power.

Consequently it is obvious that the dip workings will be easier ventilated than the rise workings, by the proportion which this excess bears to the whole ventilating power employed.

In the case just stated we have, of course, taken no account of furnace power. It is perfectly general and applies to the case of natural ventilation, as well as to that where artificial means are adopted.

(37.)—In the case of furnace ventilation we may find the difference of temperature at which the air reaches the furnace from the two sets of workings by using the formulæ [71] and [38], as follows:—

$$\left.\begin{array}{l}\text{Temperature of Return Air Dip}\\ \text{Workings [71] .....}\end{array}\right\} = t + \frac{m}{a} - \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(1-\sin\alpha)\left(\epsilon^{2al+ad}+\epsilon^{ad}\right)+\frac{m}{a}(2\sin\alpha)\epsilon^{al+ad}}{\epsilon^{2al+2ad}}$$

$$\left.\begin{array}{l}\text{Temperature of Return Air Rise}\\ \text{Workings [38] .....}\end{array}\right\} = t + \frac{m}{a} - \frac{t-\theta-\frac{m}{a}+\frac{m}{a}(\sin\alpha+1)\left(\epsilon^{2al+ad}+\epsilon^{ad}\right)-\frac{m}{a}2\sin\alpha\,\epsilon^{al+ad}}{\epsilon^{2al+2ad}}$$

And subtracting, we get the excess of Temperature of Return Air from the Dip Workings,

$$= \frac{m}{a}\left\{\frac{\left(\epsilon^{2al+ad}+\epsilon^{ad}\right)\{-(1-\sin\alpha)+\sin\alpha+1\}-4\sin\alpha\,\epsilon^{al+ad}}{\epsilon^{2al+2ad}}\right\}$$

$$= \frac{m}{a}\,2\sin\alpha\left\{\frac{\epsilon^{2al}-2\,\epsilon^{al}+1}{\epsilon^{2al+ad}}\right\}$$

(38.)—These results are curious and interesting, as they show that the excess of temperature is independent on the relative temperature of the earth and the air at bank, from which we may conclude that as far as the influence of internal heat is concerned the same relative facility exists in favour of dip workings in summer as in winter, and that even in case the whole average temperature of the workings were below the bank temperature, so that the air would be actually cooled instead of heated in its passage through the mine, still it would be less cooled in the dip workings than in the rise workings, and the relative facility of ventilation would remain as before.

(39.)—As an example of the application of this formula, we will suppose the total length of the workings (*Figs.* 1 *and* 2) to be 2,000 fathoms, and the extreme height, to the rise or fall to the dip, to be 100 fathoms. The quantity of air circulating = 20,000 cubic feet per minute, and the periphery of the workings thirty-eight feet.

Then $d = 200$

$l = 1000$

$m = \cdot 146$ or 1° Fah. for forty-one feet of descent.

$$a = \cdot 316 \frac{38}{20{,}000} = \cdot 0006$$

$$\text{sin. } \alpha = \frac{100}{1000} = 0 \cdot 1$$

Then excess of temperature of dip in rise workings

$$= \frac{\cdot 146}{\cdot 0006} \times 0 \cdot 2 \left\{ \frac{\epsilon^{1 \cdot 3} - 2\epsilon^{\cdot 6} + 1}{\epsilon^{1 \cdot 2 3}} \right\} = 8 \cdot 789$$

so that we have 20,000 cubic feet of air, heated nearly 9° higher by passing through the dip workings, beyond what it was heated in passing through the air workings, which is equal to a consumption of fuel of about 1-3rd lb. per minute.

(40.)—We now proceed to examine the influence of internal heat upon the ventilation generally, for it must be borne in mind, that, although, in all cases it increases ventilation, as between dip and rise workings, yet it is quite possible that, at the same time, it may diminish the ventilation taken absolutely, that is to say, that under certain conditions the air passing through the workings is brought to the upcast shaft at such a temperature as to decrease the effect of the furnaces or whatever other ventilating power may be employed.

Now, in considering this question we might simplify it very much if in the consideration of a system such as is represented in *Figs.* 1 *and* 2, where the bottom of the shafts are at the same level, we could confine our attention to the upcast shaft, and conclude that if the air reaches the bottom of the upcast at a lower temperature than it is at the bottom of the downcast the ventilation would be decreased. Or, if on the contrary, it reaches the upcast at a higher temperature than it has at the foot of the downcast, then the ventilation would be increased. Now, although this may be perfectly true as regards the ventilation created by the shafts, we cannot correctly assume the conclusion as a general one, because we must also take into account the ventilating power of the workings themselves, which being at different temperatures, will, of course, influence the final result.

We ought, in fact, to take the formula given in our former paper [2], when the ventilating power is expressed by

$$39{\cdot}74\left\{\frac{D}{459+T}+\frac{F_1}{459+T_1}+\&c.-\left(\frac{R_1}{459+\theta_1}+\&c.+\frac{d}{459+t}\right)\right\}$$

and replacing the symbols T, T_1, θ_1, t, &c., by their values, as given by the various equations of mean temperature given above, compare the final ventilating power of the respective systems under consideration.

To do this in general symbols, so as to exhibit a general result, would be useless, because there are so many varying elements in the question, all of which have their independent effect, such as the depth of the shafts, and the length and inclination of the strata, but by taking the definite values, corresponding to any two systems which we may wish to compare, the question may be easily worked out.

(41.)—We proceed to give an example, and, suppose we wish to compare the ventilation of the two systems represented in the diagrams below,

Fig. 5.

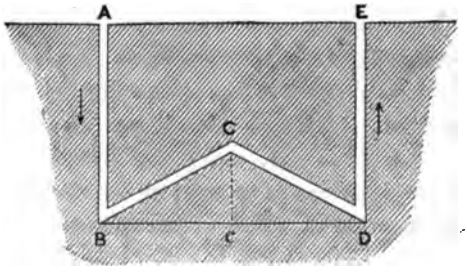
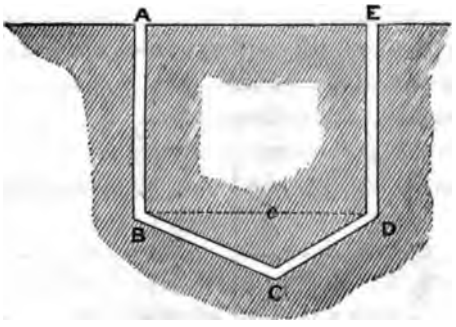


Fig. 6



Let A B = 200 fathoms = D E = d

B C = 1000 „ = C D = l

C c = 100 „

Let Q = the quantity of air passing be 20,000 feet per minute,

P = Periphery of shafts and passages = 38 feet,

m the coefficient for the increase of the earth's temperature = 0·146 which corresponds to 1° for each 41 feet of descent,

$a = \cdot 316 \frac{P}{Q}$ as will be shewn hereafter, when we come to seek its numerical value, therefore, in this case

$$a = \cdot 316 \frac{38}{20{,}000} = \cdot 0006$$

$$\sin \alpha = \frac{100}{1000} = 0 \cdot 1$$

and let

$t = 47°$

$\theta = 50°$

Then Mean Temperature of downcast [6], or

$$T_1 = t + \frac{md}{2} - \frac{m}{a} + \frac{t - \theta - \frac{m}{a}}{ad}(e^{-ad} - 1)$$

$$= 47 + \frac{29 \cdot 2}{2} - \frac{\cdot 146}{\cdot 0006} + \frac{-3 - \frac{\cdot 146}{\cdot 0006}}{200 \times \cdot 0006}\left(\frac{1}{2 \cdot 718^{\cdot 12}} - 1\right) = 50°$$

which is the mean temperature of the downcast.

INTAKE RISE WORKINGS. [17].

$$T_{2R} = t + m\,d - \frac{m}{2}\,l \sin a + \frac{m}{a}\sin a + \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin a + 1)\,\epsilon^{ad}}{a\,l\,\epsilon^{ad}}(\epsilon^{-al} - 1)$$

$$= 47 + 29{\cdot}2 - 7{\cdot}3 + 24{\cdot}33 + \frac{-246{\cdot}3 + 267{\cdot}63 + 2{\cdot}718^{12}}{0{\cdot}6 \times 2{\cdot}718^{12}}\left(\frac{1}{2{\cdot}718^{0{\cdot}6}} - 1\right) = 56°{\cdot}29$$

RETURN AIR RISE WORKINGS, [29].

$$T_{3R} = t + m\,d - \frac{m}{2}\,l \sin a - \frac{m}{a}\sin a + \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin a + 1)\,\epsilon^{ad} - \left(\frac{m}{a}\,2 \sin a\right)\epsilon^{al+ad}}{a\,l\,\epsilon^{al+ad}}(\epsilon^{-al} - 1)$$

$$= 47 + 29{\cdot}2 - 7{\cdot}3 - 243{\cdot}3 \times 0{\cdot}1 + \left\{\frac{-246{\cdot}3 + 267{\cdot}63 \times 1{\cdot}128 - 48{\cdot}66 \times 2{\cdot}718^{72}}{0{\cdot}6 \times 2{\cdot}718^{72}}\left(\frac{1}{2{\cdot}718^{6}} - 1\right)\right.$$

Whence $T_{3R} = 60°{\cdot}88$.

UPCAST SHAFT [45].

$$T_{4R} = t + \frac{m}{2}\,d + \frac{m}{a} + \frac{t - \theta - \frac{m}{a} + \frac{m}{a}(\sin a + 1)(\epsilon^{2al+ad} + \epsilon^{ad}) - \frac{m}{a}\,2 \sin a\,\epsilon^{al+ad}}{a\,d\,\epsilon^{2al+ad}}(\epsilon^{-ad} - 1)$$

$$= 47 + 14{\cdot}6 + 243{\cdot}3 + \left\{\frac{-246{\cdot}3 + 267{\cdot}63 \times 4{\cdot}871 - 243{\cdot}3 \times 0{\cdot}2 \times 2{\cdot}718^{72}}{{\cdot}12 \times 3{\cdot}743}\right\}(-{\cdot}113) = 63°{\cdot}9$$

So that we have the following temperatures,

Air at bank.....	50°
Mean temperature of downcast	50°
„ intake	56°·29
„ returns	60°·88
„ upcast.....	63°·9

and, substituting these values in our formula, we get ventilating column

$$= 39{\cdot}74\left\{\frac{200}{459+50}+\frac{100}{459+60{\cdot}88}-\left\{\frac{100}{459+56{\cdot}29}+\frac{200}{459+63{\cdot}9}\right\}\right\}$$

$$= 0{\cdot}3440 \text{ lbs. per square foot,}$$

which is the amount of natural ventilation of this system. If we compare this with the ventilation that would have arisen simply from the difference of temperature of the two shafts, supposing the upcast to have been brought to the same average by a furnace, it would have been

$$39{\cdot}74\left\{\frac{200}{459+50}-\frac{200}{459+63{\cdot}9}\right\} = {\cdot}4171 \text{ lbs. per square foot,}$$

so that the negative effect, as we may term it, of the workings is ·4171 — ·3440 = ·0731 lbs. per square foot, which represents the loss of ventilating power from the rise workings as compared with level workings wherein the air was equally heated in its passage to the upcast shaft. It must be borne in mind that this is only a relative loss as compared with another system, the absolute effect being a gain to the extent of 0·3440 lbs square foot.

(42.)—Taking now the system, *Fig.* 6, where the only difference is in the inclination of the workings being to the dip instead of the rise, and making use of the formulæ for the dip workings, we shall find the following temperatures:—

Air at Bank.....	50°
Mean Temperature of Downcast Shaft	50°
Mean Temperature of Intake	58°·56
Mean Temperature of Return	71°·03
Mean Temperature of Upcast Shaft	73°·2

so that we get the ventilating column,

$$39{\cdot}74\left\{\frac{200}{509}+\frac{100}{517{\cdot}56}-\left\{\frac{100}{529{\cdot}93}+\frac{200}{532{\cdot}2}\right\}\right\}$$

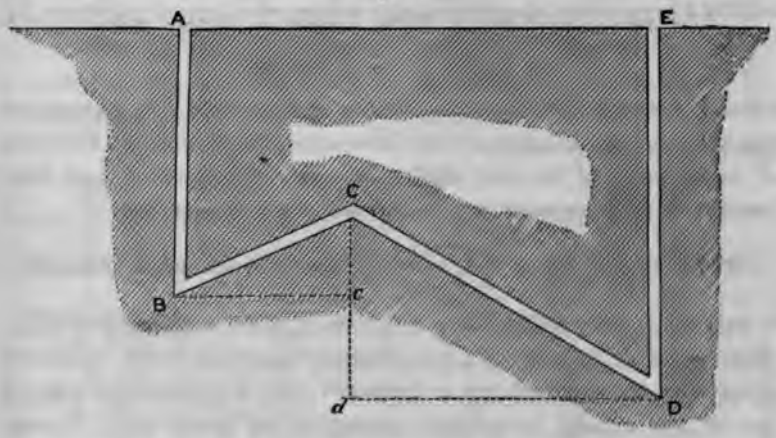
$$= {\cdot}9135 \text{ lbs. per square foot.}$$

So that, comparing the two systems, we get

		lbs.	
Natural Ventilation from Dip Workings	.....	·9135	per sq. foot.
Ditto Rise Ditto	.....	·3440	"
Difference in favour of the Dip Workings	....	·5695	"

(43.)—As a second example, we will take the system represented in

Fig. 7.



Let C c = 30 fathoms
c d = 130 "
A B = 100 " B C = 300 fathoms
E D = 200 " C D = 1000 "
Temperature of Air at Bank, ... $\theta = 40$
Ditto of Earth at Surface, ... $t = 47$

Quantity of air circulating, and area of passages the same as in the last example, and therefore,

$$a = \cdot0006$$
$$m = \cdot146$$

Then we should find if A B be the downcast,

Mean Temperature of Downcast,	A B	by formula	[6]	..40°·23
Ditto of Intake,	B C	"	[17]	..42°·46
Ditto of Return,	C D	"	[28]	..48°·33
Ditto of Upcast,	D E	"	[42]	..54°·36

and the Ventilating column,

$$=39{\cdot}74\left\{\frac{100}{459+40{\cdot}23}+\frac{130}{459+48{\cdot}83}-\left(\frac{30}{459+42{\cdot}46}+\frac{200}{459+54{\cdot}36}\right)\right\}$$

$= -0{\cdot}03259$ lbs. per sq. foot, which is negative, so that the effect of the internal heat is in this case to diminish the ventilation.

Having thus found the amount of ventilation due to this arrangement, let us now suppose the air to be reversed, and that E D is made the downcast and A B the upcast.

We shall then find

Mean Temperature	of Downcast,	D E [6]	40°·97
Ditto	of Intake,	D C [17]	49°·30
Ditto	of Return,	B C [28]	53°·51
Ditto	of Upcast,	A B [42]	54°·80

and the ventilating column

$$=39{\cdot}74\left\{\frac{200}{459+40{\cdot}97}+\frac{30}{459+53{\cdot}31}-\left(\frac{130}{459+49{\cdot}30}+\frac{100}{459+54{\cdot}80}\right)\right\}$$

$= 0{\cdot}3247$ lbs. per square foot, which, being positive, shows that the effect of the internal heat is to increase the ventilation.

This comparison shows us that in such a case the advantage is in favour of the short upcast as far as regards natural ventilation. The same will be the case with mechanical ventilators, but it would be very different with furnace ventilation, as then the extra length of hot column in the deep upcast would much over-balance the natural tendency of the air to take the opposite course.

If, for instance, we suppose a furnace to be placed alternately at the bottom of A B and C D, and that the air is raised to an average of 141° in each, the ventilating columns will be

for A B downcast

$$=39{\cdot}94\left\{\frac{100}{459+40{\cdot}23}+\frac{100}{459+48{\cdot}83}-\left(\frac{30}{459+42{\cdot}26}+\frac{200}{459+141}\right)\right\}$$

$= 2{\cdot}511$ lbs. per square foot;

and for E D downcast

$$=39{\cdot}74\left\{\frac{200}{459+40{\cdot}97}+\frac{30}{459+53{\cdot}31}-\left(\frac{130}{459+49{\cdot}30}+\frac{100}{459+141}\right)\right\}$$

$= 1{\cdot}4365$ lbs. per square foot,

so that the power of the furnace in the deep shaft not only overcomes the natural tendency to upcast through A B to the extent of 0·3247 lbs. per square foot, but also gives a ventilating power of 1·0345 lbs. per square

foot above the shorter upcast at the same average temperature. It is true that the furnace power would require to be somewhat greater to maintain the long upcast at the same average as the short one; but we shewed in a former Paper to what extent this would be the case, and that if shafts were properly protected from the effects of moisture the difference would be very trifling indeed.

This example shews, therefore, that it is quite impossible to lay down a positive rule as to the proper position of the shafts, for it is evident that it depends both upon the nature of the workings as regards extent and inclination, and also upon the system of ventilation proposed to be adopted. It may, however, be affirmed that *when furnace ventilation is used, the upcast should, as a general rule, be to the extreme dip*, for the instances would be very rare, and the circumstances very exceptional which would allow it to be placed to the rise without detriment. The cases would, in fact, be limited to those of very great variation of surface level, when it might be possible that the deepest shaft was actually to the rise of the strata.

(44.)—We next proceed to determine the numerical value of the constant a which determines the quantity of heat imparted to the air by contact with the surface of the earth.

It is evident that this will be

1st.—Directly as the surface of contact (P).

2nd.—Inversely as the quantity (Q) of air passing in a given time, or inversely as the area (A) of the passage multiplied by the velocity (V) of the air, or

$$a \propto \frac{P}{A\,V} \text{ so that we may assume}$$

$$a = b\frac{P}{A\,V} = b\,.\,\frac{P}{Q}$$

In order to determine the value of a and b we must have recourse to observations, and we shall take that recorded by Mr. Wood, in his Paper published in Vol. I. of the "Transactions," *page* 12, being the result of an experiment made at Seaton Pit.

We shall first deduce a value of a from the downcast shaft, and for that purpose make use of the formula [4],

$$T_1 = t - \frac{m}{a} + m\,d - \frac{t - \theta - \frac{m}{a}}{\epsilon^{a\,d}}$$

Here we have,

T_1 the temperature of the air at the bottom of the shaft ..... 49°·5

t the temperature of the earth at top, which we shall assume as the mean annual temperature of the locality ..... 47°

θ = temperature of air at bank ..... 44°

m the coefficient for the increase of temperature of the earth in descending, which we shall take at 1° in 41 feet, or $\frac{1}{41}$, or in fathoms $\frac{6}{41}$ ..... 0·146

d the depth in fathoms 260

Consequently,

$$49{\cdot}5 = 47 - \frac{0{\cdot}146}{a} + 260 \times 0{\cdot}146 - \frac{47 - 44 - \frac{0{\cdot}146}{a}}{2{\cdot}718^{260a}}$$

$$35{\cdot}46 = \frac{{\cdot}146}{a} + \frac{3 - \frac{{\cdot}146}{a}}{2{\cdot}718^{260a}}$$

whence a may be found = ·00105

$$\text{but } b = a \,.\, \frac{A\,V}{P} \text{ or } a\,\frac{Q}{P} \;\therefore\; b = \frac{Q}{P}\,{\cdot}00105$$

now, in this case, the quantity of air passing was 7002 feet per minute = Q, and the periphery of the earth exposed was about 21½ feet, deducting six inches on each side for the brattice,

$$\therefore\; b = \frac{7002}{21{\cdot}5} \times {\cdot}00105 = 0{\cdot}3419, \text{ and, therefore,}$$

$$a = 0{\cdot}3419 \cdot \frac{V\,A}{P} = 0{\cdot}3419 \cdot \frac{Q}{P}\cdot$$

We shall now, in like manner, seek the value of a from the workings, for which purpose we make use of the equation [9],

$$T_2 = T_1 + (t - T_1 + m\,d + \frac{m}{a} \text{ sin. } a)\left(1 - \frac{1}{e^{a\,l}}\right) - m \text{ sin. } a\,l,$$

the inclination of the workings is not mentioned, but as they comprised the workings round the shaft walls it is probable they extended as much to the dip as to the rise. We shall, therefore, make $a = 0$, and the equation becomes,

$$T_2 = T_1 + (t - T_1 + m\,d)\left(1 - \frac{1}{e^{a\,l}}\right)$$

where T_1 = 49°·5

t = 47°

$m\,d$ = 260 × ·146 = 37°·96

l = 3036 ÷ 6 = 506 fathoms

T_2 = 62°·5,

Wherefore,

$$62{\cdot}5 = 49{\cdot}5 + (47 + 37{\cdot}96 - 49{\cdot}5)\left\{1 - \frac{1}{2{\cdot}718^{506\,a}}\right\}$$

$$\therefore \frac{13}{35{\cdot}46} = 0{\cdot}3666 = 1 - \frac{1}{2{\cdot}718^{506\,a}}$$

$$\text{or } \frac{1}{2{\cdot}718^{506\,a}} = {\cdot}6334$$

$$\text{whence } a = {\cdot}00090256$$

$$\text{but } b = \frac{Q}{P}\,a = \frac{Q}{P}\,{\cdot}00090256$$

Now, Q is as before, 7002; and P is stated to have been on an average 20 feet.

$$\therefore b = \frac{7002}{20}\,{\cdot}00090256 = {\cdot}315986$$

$$\therefore a = {\cdot}315986\,\frac{P}{Q}$$

On comparing the value of b as obtained from the downcast shaft with this value obtained from the workings, we see that then the former is about 7 per cent. greater than the latter. This we might expect, inasmuch, as in the shaft we took no account of the brattice, which, doubtless to some extent, communicated heat to the air; the average temperature of the upcast being $3\frac{1}{2}$ degrees above that of the downcast, which is about $\frac{1}{6}$th of the average excess of the earth's temperature above the average of the air in the downcast, and the surface being $\frac{14}{20}$ths of the earth's surface, so that the effect of the brattice, if it be supposed to give out heat as readily as the earth, would be $\frac{14}{20} \times \frac{1}{6} = \frac{1}{8{\cdot}5}$th of the effect produced by the earth, which would increase the value of b by about 12 per cent., but as wood does not conduct heat so well as the coal measures in the ratio of one to four, the effect of the brattice would only be about $\frac{1}{3\frac{1}{4}}$th of that of the surface of the shaft. This would, therefore, only account for a difference of about 3 per cent. in the value of b, but as we shall presently show that there are other causes operating in the shaft, as well to cool as to heat the air, and from which the workings are comparatively free, we are disposed to regard the value of b obtained from the workings as the most to be relied on, and to be as near the true value as we can arrive at in the present state of our experimental knowledge of the subject.

Were we now to seek to determine the value of a from the upcast shaft

we should find it impossible, as indeed ought to be the case, for it is evident that the temperature of the air could not be reduced below that of the earth, as it appears by Mr. Wood's experiment to have been, so that it is evident that extraneous cooling influences had been in operation in the upcast shaft, the nature of which we will hereafter point out, but the extent of whose operations we must defer to a future period.

(45.)—The quantity of heat given out by the workings of a mine is by no means inconsiderable, as will be shewn by the following calculation based upon the experiment recorded by Mr. Wood, and from which we have just found the values of a and b.

We have here 7002 cubic feet of air per minute, heated from 49°·5 to 62°·5 or 13° Fahr., but the weight of a cubic foot of air at 49°·5 Fahr. is ·07814 lbs. or 12·796 cubic feet = 1 lb., therefore the number of pounds of air heated 1° would be $\frac{7002}{12{\cdot}796} \times 13 = 7113$ lbs., and since the specific heat of air is ·2669, that of water being unity, we get the equivalent of water 7113 × ·2669 = 1898 lbs. raised 1° Fahr. per minute, or 113880 lbs. raised 1° per hour, but 1 lb. of coal will raise 11592 lbs. of water 1°, therefore the heat given out per hour is equal to that given out by the perfect combustion of $\frac{113880}{11592} = 9{\cdot}829$ lbs. of coal per hour.

The surface from which this was given out was estimated by Mr. Wood at 60720 square feet, so that we have the heat given off per square foot of surface equal to the combustion of $\frac{9{\cdot}828}{60720} = {\cdot}00016185$ lbs. of coal per hour for each square foot of surface.

It may be curious to compare this with the amount of heat estimated to be given off annually from the surface of the earth. Fourier calculated, and we believe Poisson concurred in his opinion, that the amount of heat given off annually would only suffice to melt a stratum of ice of $\frac{1}{10}$th of an inch in thickness. This, for each foot of surface, would be about $\frac{1}{8}$th of a lb., and as the latent heat of ice is 142°·6 the amount of heat would be $\frac{142{\cdot}6}{8} = 17\frac{1}{2}$ calories.

But we have shown that the surface of the workings at Seaton gave off 113880 calories per hour from a surface of 60720 square feet, = 1·875 per square foot, which per annum = 1·875 × 24 × 365 = 16425 calories, or nearly 1000 times more than is estimated to be given off at the surface.

In the case of Tyne Main Colliery, also recorded by Mr. Wood, the quantity of air, taking the mean of the experiments, on 15th January, was 36876 feet raised 18°, which reduced to its equivalent of water, is equal to $\frac{36876}{10{\cdot}076} \times 18 \times {\cdot}2669 = 13845$ lbs. raised 1° per minute, which is equal to a consumption of 71·67 lbs. of coal per hour.

If we reduce the above to mechanical force, taking 1lb. of water raised 1° as equal to 772lbs. raised 1 foot high, we get for Seaton Colliery the mechanical effect of the workings = 1898 × 772 lbs. raised 1 foot high per minute.

We may here point out that in the case of Seaton Colliery, as recorded by Mr. Wood, that gentleman has expressed himself in a manner which might lead to a wrong impression of the amount of heat imparted to the air by a series of workings.

He has remarked that a volume of air of 7002 feet per minute was raised 3½° by passing along 3036 feet of workings, exposing a surface of 60720 square feet, whereas the effect is in reality much greater. The 3½° is the excess of the mean temperature of the upcast shaft over that of the downcast, and so far it represents the effect of the workings in the creation of a ventilating column, but the actual heat imparted by the workings is much greater, and is, in fact, the difference between the temperature at the bottom of the downcast and upcast shafts, or 62°·5 — 49°·5 = 13°; of this 13° a large quantity is lost in ascending the upcast, so that the average excess in the upcast over the downcast is reduced to 3½°.

If no heat had been lost in the upcast we should have had a ventilating column due to a difference of about 15½° Fahr.

(46.)—We think such facts as these are striking evidence of the existence of an immense store of heat within the globe. When we reflect that the surface exposed, in the case of Seaton Colliery, is only about 60720 square feet, or not more than $\frac{1}{92{,}000{,}000{,}000}$th part of the surface of the sphere at that depth, and that the depth below the surface is only about the $\frac{1}{27000}$th part of the diameter, we cannot but be struck at the enormous quantity of heat thus continually supplied from below.

If we make the calculation we find that supposing the whole surface to be exposed at that depth, it would be equal to the combustion of upwards of 110,000 tons of coals per second, a quantity that to our puny

notions of chemical operations, does certainly appear in no small degree startling, and which may well strike us with awe when we reflect how thin a shell of earthy matter separates us from the terrific agencies that lie for the present slumbering peaceably beneath our feet.

(47.)—We are desirous to direct attention more particularly to this point, as it has been suggested that the increase of temperature of the air in the mine might be accounted for on different grounds.

It is well known that the capacity for heat of æriform fluids is modified by variations of pressure, so that when they are compressed their capacity is diminished, and the heat set free raises the sensible temperature, and *vice versa*. Now, it is supposed that the increase of temperature in descending may be accounted for in this manner without reference to the internal heat of the globe.

(48.)—There can be no doubt that some increase is due to this cause, and that air entering the downcast at a temperature T has its capacity diminished when it reaches the bottom, and, consequently, its temperature, as indicated by the thermometer, increased.

It is estimated, (we believe, by the late Professor Daniell,) that the variation of temperature in the atmosphere is about 1° Fahrenheit for each 300 feet of variation of level, so that in the case of Seaton Pit, to which we have above referred, the rise of temperature due to this cause ought to have been $\frac{1560}{300} = 5°{\cdot}2$. Now, by referring to the observations it will be seen that the actual increase was 5°·5, and so far, doubtless, it may be thought that the arguments of the heat developed being due to condensation of the air is fully borne out by observation, but if we look a little further we shall find that the hypothesis becomes untenable.

The air in passing through the workings was further heated from 49·5 to 62·5, or 13°. *This extra heat could not be due to condensation.* Heat given out under condensation manifests itself instantaneously, and the whole maximum effect would be necessarily produced at the bottom of the downcast shaft, whereas we find little more heat observed there than what is due to the contact with the earth.

We are, however, disposed to think that the estimate just given of the amount of heat liberated by condensation is below the actual result.

It has been ascertained by direct experiment, that if

T be the temperature of a mass of air reckoned from a point 461° below the zero of Fahr. scale.

T^1 the temperature of the same air reckoned from the same point after compression.

p the pressure in atmospheres to which the air is compressed, including its original pressure.

$T^1 - T$ the elevation of temperature due to the compression, then

$$T^1 - T = T\,(p^{\frac{1}{4}} - 1)$$

Now, in the case of Seaton Colliery, if the pressure at bank had been 30 inches of mercury or 1 atmosphere, it would have been 31·8645 inches, or 1·06215 atmospheres at the bottom of the downcast, and since

$$T = 461° + 44° = 505°$$

$$T^1 - T = 505\,(\overline{1{\cdot}06215}^{\frac{1}{4}} - 1) = 7°{\cdot}6558,$$

which is one-half more than is given above.

We may here point out in corroboration of this result another calculation based upon a principle which may be somewhat new to some of the Members of the Institute.

The doctrine of this convertibility of heat into force, and *vice versa* of force into heat, has of late years been removed from the province of speculation into that of fact, and we believe the time is not far distant when it will be placed beyond a doubt that heat, light, electricity, and gravitation are all, if not identical, at least so far cognate powers, and so interwoven in their effects that they will practically be considered as only so many modifications of one general influence coextensive with space itself.

Be this as it may, as regards heat, it has been shown by Mr. Joule, that an amount of that influence which we call heat, which would raise 1 lb. of water 1° Fahr. is identical, in whatever form it may present itself, with a force which would raise 772 lbs. to the height of 1 foot. This being so, the inverse of the proposition must also be true, viz., that a weight of 1 lb. descending 772 feet must be equivalent to raising 1 lb. of water 1°. Let us then try this upon the air descending the shaft at Seaton, which, by an independent process, we have calculated would be raised in temperature by 7°·66.

We have here 1 lb. of air descending 1560 feet, consequently the equivalent in heat is 1 lb. of water raised $\frac{1560}{772} = 2°{\cdot}021$, but the specific heat of air being ·2669 we should have the temperature by which the air was raised $2{\cdot}021 \times \frac{1}{{\cdot}2669} = 7°{\cdot}57$.

This agrees remarkably nearly with the former determination, and is at any rate an interesting case of coincidence of results arrived at by two entirely independent processes.

(49.)—It will be remembered that in determining the value of a we found it somewhat greater from the downcast shaft than from the workings, and we accounted for this, in some degree, from the temperature communicated by the brattice, but this only to a very small extent.

Let us, then, see what would be the temperature due to the contact with the earth at the bottom of the downcast, making use of the value of a determined from the workings, or $a = 0{\cdot}316\ \frac{P}{Q}$

Now Q = 7002, and P = the periphery.

This in the shaft = 21·5 feet, but we must also allow for the brattice.

Since the surface of the brattice was $\frac{1}{20}$ths of that of the earth exposed in the shaft, and since the mean excess of temperature of the upcast was about $\frac{1}{8}$th of that of the average of the earth's surface, we should have, as we showed before, an effect = $\frac{1}{20}$ths × $\frac{1}{8}$th = $\frac{1}{160}$ths, but, since the power of transmitting heat in wood is only about $\frac{1}{4}$th of that of the earth, this must be again reduced in the proportion of $\frac{1}{160}$ths × $\frac{1}{4}$th = $\frac{1}{640}$ths, so that the surface of the brattice may be taken

$$\text{as} = 21{\cdot}5 \times \frac{7}{240} = 0{\cdot}62, \text{ consequently,}$$

$$P = 21{\cdot}5 + 0{\cdot}62 = 22{\cdot}12$$

$$\therefore\ a = 0{\cdot}316 \cdot \frac{22{\cdot}12}{7002} = 0{\cdot}000998$$

And, making use of this in formula [4],

$$T_1 = t - \frac{m}{a} + m\,d - \frac{t - \theta - \frac{m}{a}}{e^{a\,d}} \text{ we get,}$$

$$T_1 = 49{\cdot}15$$

To this we must add the increase due to condensation of the air, = 7°·66, which would give, as the temperature at the bottom of the shaft, 49·15 + 7·66 = 56·81, or 7°·31 above the actually observed temperature.

What, then, has become of the 7°·31? It is evident they have been absorbed in some way, and, we believe, the probable cause to be the absorption of heat due to the increased quantity of moisture taken up by the air.

This cooling influence would take effect in the shafts rather than the workings, which are comparatively dry, and we may, therefore, expect at least the same, or even an increased cooling effect in the upcast shaft, because the air being then at a higher temperature than in the downcast, it would absorb moisture more readily. In a future paper we shall investigate the effect of such hygrometric changes, both as reducing the temperature and as affecting the resistance to the ventilating power, at present we merely point out the tendency to reduce the temperature of the air, and the amount to which we believe it to have acted in the shafts at Seaton.

Let us suppose that a similar cooling effect was produced in the upcast shaft, and that it was then augmented in the proportion due to the relative capacities for moisture of the air at the temperature of the downcast and upcast respectively.

Now, this capacity varies as $(2)^{\frac{T-32}{27}}$, where T is the temperature of the air, and as the absorption of moisture would take place chiefly when the temperature was the highest, we shall assume not the mean but the maximum temperatures of the two shafts whereupon to base the calculation, *i.e.*, 49·5 and 62·5

therefore the capacities would be at $(2)^{\frac{62\cdot5-32}{27}} : 2^{\frac{49\cdot5-32}{27}}$

as $(2)^{\frac{30\cdot5}{27}} : (2)^{\frac{17\cdot5}{27}} :: 2\cdot138 : 1\cdot567$

Consequently, the reduction of temperature in the upcast would be $7\cdot31 \times \frac{2\cdot188}{1\cdot567} = 10°\cdot20$. To this we must add the reduction due to rarefaction, which would, of course, be the same as the gain by condensation in the downcast, or 7°·31, so that the whole reduction thus accounted for is 10·29 + 7·31 = 17°·51. But supposing the air to have reached the bottom of the upcast as it did at 62°·5 it would, had there been no evaporation going on, have been affected by the contact with the earth in passing up the upcast, and it remains to be seen what this effect would have been. For this purpose we make use of the formula [34], observing that $d = d'$ and $a = \cdot000998$, as found above, and $T_s = 62°\cdot5$, so that the formula becomes

$$T_t = t + \frac{m}{a} - \frac{t - T_s + m\,d + \frac{m}{a}}{\epsilon^{a\,d}}$$

and we find

$T'_4 = 63{\cdot}21$ which ought to have been the temperature at the top of the upcast, but this was, by observation, only 46°, so that there was an actual loss in the upcast of ..... 17·21

of which we have accounted for

By evaporation	10·20	
By rarefaction.....	7·31	..... 17·51
	Difference	0·30

The result of this calculation, agreeing as it does so nearly with the actually observed result deserves attention. We shall, therefore, briefly recapitulate the process by which we arrived at it.

We first investigated and framed equations representing the law of variation of temperature of the air in passing along the shafts and workings.

We then deduced from actual observation in the workings a numerical value for the constants of our equations. Having done this, we computed, by means of these equations, the temperatures at the bottom of the downcast and top of the upcast shafts.

To the former of these we added the computed value of the increase due to the compression of the air in descending the downcast. This we added to our former computed value as due to the internal heat, and we found by comparison with the actually observed temperature a certain loss, which we attributed to the heat absorbed by the evaporation of water in the shaft.

The upcast shaft being only separated from the downcast by a brattice, they were in precisely similar circumstances as regards moisture, and we, therefore, concluded that whatever loss had taken place in the downcast from evaporation, a similar loss augmented in the ratio of the increased capacity of the air for moisture due to its increased temperature would take place in the upcast, to this loss we added that due to the increase of capacity for heat consequent upon the rarefaction of the air in passing from the bottom to the top of the upcast, and which in amount was, of course, exactly equal to the gain due to the correlative cause in the downcast, and we found the sum of losses deducted from the calculated value of the temperature at the top of the upcast gave very nearly indeed the actually observed result: or

Loss by observation ..... 17°·21

Ditto, by calculation..... 17°·51

The difference being only 0°·30.

We may infer from this that our deduced value of a or rather of b,

from which a is derived, and, therefore, also the form of our equations whereby it was derived, are substantially correct, since they give results when applied to the shafts as well as the workings, which agree with actual observation, after making the requisite corrections for hygrometric and barometric influences.

(50.)—The chief practical point to which we deem it right to direct attention is the great importance of adopting means to prevent the loss of heat by evaporation. This, we believe, to be the main evil attendant upon *furnace* ventilation. As we pointed out in a previous paper the actual loss of temperature in upcast shafts is most serious, and whilst we believe the system of ventilation by furnace to be the most effective and least liable to derangement, because a furnace is the simplest of all machines, we cannot but perceive that it loses much of its inherent power by the rapid absorption of the heat attendant upon the evaporation which goes on so extensively in a wet or damp upcast. Other systems of ventilation require less attention as regards this point, although, as we may see in the instance above given, they may easily lose the whole of the natural ventilating power, which is by no means inconsiderable, but furnace ventilation specially demands attention to this point, and it is because we believe the evil to be great, and the remedy to be practicable, that we would again press upon the members of this Institute the importance of directing their attention and energies to the discovery of the most efficient and simple means for securing to the furnace its full and perfect action as a ventilating power.

With respect to the effect of the heat liberated by the compression of the air in passing down the shaft and absorbed again in passing up the upcast, we are of opinion that, *per se*, it has no influence on the ventilation. The average amount of rarefaction due to it is the same in both shafts, so that the only result is to render the whole of the air in the mine specifically lighter, but it gives no advantage to the one shaft over the other.

Inasmuch as it renders the air specifically lighter it certainly decreases the weight of air, and consequently the value of air as a supporter of life and combustion; on the other hand, it is probable that the friction in the workings is somewhat reduced, and so an extra quantity of air may pass, but these are niceties which we think may well be passed over.

We are desirous, however, of expressing our opinion, that excepting to the extent just mentioned, the increase of temperature due to the compression of the air in descending does in no way affect the ventilation

of the mine, but, on the other hand, the influence of internal heat upon the air has a considerable effect, as may be experienced in many cases in the range of ordinary practice.

We have endeavoured in this paper to investigate the amount and nature of this influence, and we trust on a future day to continue the subject with reference to the hygrometric changes to which the air is subject in its passage through the workings and shafts of a mine.

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(21 to 30.)—Corresponding expressions for the equations of temperature, final and mean temperatures for the dip workings and shafts.
(31.)—Note upon the above expressions.
(32 to 35.)—Generalization of these expressions to suit any series of shafts and workings, whether to the rise or dip, and formulæ exhibiting the final and mean temperature after a change of inclination.
(36.)—Comparison, by means of these formulæ of the mean temperature in the upcast shafts, of similar workings to the rise and dip respectively.
(37.)—Comparison of final temperature of return air in the same cases.
(38.)—Excess in favour of dip workings, independent on relative temperatures of air and earth at the top of the downcast shaft.
(39.)—Numerical example of formulæ in Section (37).
(40.)—Examination of influence of internal heat on ventilation generally.
(41.)—Examination of first special case with numerical values, and computation of ventilating columns for rise workings.
(42.)—Ditto for dip workings, and comparison of the results with those obtained in last section, showing balance in favour of dip workings.
(43.)—Examination of second special case, with computation of ventilating columns and comparison between deep and shallow upcast shaft, showing under what circumstances the shallow shaft may be made the upcast with advantage.
(44.)—Determination of numerical value of the constant (a).
(45.)—Remarks on the quantity of heat given out in the workings of a mine, and estimated amount of the same.
(46.)—Strong evidence of an immense store of central heat.
(47.)—Hypothesis of increased temperature being due to decreased capacity of air consequent upon its condensation in descending the shafts.
(48.)—Examination and refutation of the same.
(49.)—Loss of temperature, its causes explained and amount estimated.
(50.)—Concluding remarks.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

ANNIVERSARY MEETING, THURSDAY, AUGUST 7, 1856, IN THE ROOMS OF THE INSTITUTE, WESTGATE STREET, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The minutes of the Council having been read,

The PRESIDENT said, the first business to be transacted was the election of gentlemen nominated at the previous meeting.

The following gentlemen were then elected members:—Mr. Robert Robinson, Evenwood Colliery, Bishop Auckland; Mr. Peter Pickup, Rudgeley Bank, Rantenshall, near Manchester; Mr. G. Gilroy, M.E., Orrell, Lancashire.

Mr. DOUBLEDAY, the Secretary, read the Report of the Council for the past year.

After which, Mr. REID, one of the Finance Committee, read the Report of the Financial state of the Institute.

The PRESIDENT, at the termination of the Report, called attention to that portion of the minutes of the Council having reference to the proposed change, viz., of altering the day of the monthly meetings from Thursday to Friday.

Some discussion ensued on the subject, but the majority of the members present being of opinion that a change was requisite in order to ensure a better attendance of members generally, the following resolution was agreed to:—

RESOLVED,—"That the day of the Monthly Meetings be experimentally changed from Thursday to Friday, during the next four months, the hour of meeting remaining as before."

The PRESIDENT next called attention to the election of Officers for the ensuing year; and noticed the suggestion embodied in the minutes of the Council relative to the desirability of some of the Council retiring every year. Such a course was adopted by other Institutions; and the Council having taken the matter into consideration, thought it desirable that three out of the Council and one from among the four Vice-Presidents should retire each year and be ineligible for re-election that year.

Mr. LONGRIDGE, Mr. PHILIPSON, Mr. BARKAS and others, all expressed themselves as to the expediency of infusing a little "fresh blood" into the Council, with the exception of the Vice-Presidents and President, all of whom ought to remain as at present. Such a change, however, they deemed premature this year, inasmuch as they were desirous to make the matter more fully known, as it was suggested that the three of the Council who ought to be considered ineligible for re-election depended upon the number of times they attended the respective meetings during the year. Ultimately the following resolution was unanimously agreed to:—

RESOLVED,—"That no change in the election of Vice-Presidents is desirable or expedient, but that it is the opinion of this Meeting that one-fourth of the Council should retire annually and be ineligible for re-election in each succeeding year; and that the three whose attendances at the Meetings of the Council have been fewest, shall be the three ineligible for the following year."

The PRESIDENT next referred to the sale of the Society's publications, and in doing so, adverted to the Report of the Council just read, from which it would be seen that there had been a great increase in the sale of books by Mr. Reid. It would, however, be recollected that £10 was voted to Mr. Weale, the London publisher, for advertisements, and that after two years the sum of £20 had been expended, while only £15 had been received from the sale of books published by the Institute. The question which he wished to put to the meeting was, as to whether it was desirable or not to continue the £10 to Mr. Weale.

After a brief conversation it was agreed to discontinue the £10 to Mr. Weale for advertisements.

The PRESIDENT then said that it was well known that Her Majesty's Inspectors of Mines had been elected honorary members of the Institute, but as there had been six other gentlemen appointed during the past year, he wished to take the sense of the meeting as to their being placed also on the list of honorary members, and thus be on the same footing as the other Inspectors of the country. The Institute, certainly, were much obliged to one or two of Her Majesty's Inspectors, and he begged to move that the additional six Inspectors be elected honorary members.

The motion, on being put from the chair, was carried unanimously.

The voting papers were then scrutinized, when the officers for the ensuing year were elected.

The PRESIDENT then said, their next business would be to proceed with the discussion of papers which had been read. That first in rotation was the paper of Mr. Elliot, but he (the President), was sorry to say that that gentleman was not present. It was, in his opinion, a most valuable paper, and ought to be discussed properly, but, perhaps, as there was no notice given of it in the usual circulars, and as Mr. Elliot was not present, they could not well proceed with it. The next paper in rotation was that of Mr. Greenwell, but as he, also, was not present, it must share the same fate as its predecessor and stand over until he was present. The third paper was that of Mr. Longridge, and he should like to know how many members present had read it over to enable them to go on with the discussion of it. It certainly was a valuable paper and one which required considerable discussion, and, therefore, he thought that, in point of time, it had not been long enough in the hands of the members to enable them to do justice to it. Besides Mr. Thos. John Taylor had paid considerable attention to the subject, and had written a similar paper; but as he was unavoidably absent that day, this, with other reasons, justified him in suggesting the postponement of the discussion. In the meantime they might proceed with three papers, which were ready to be read. One was from Mr. Dunn, the second from Mr. Armstrong, and the third from Mr. Daglish. He, also, held in his hand another paper by Mr. Beanland, on "Mining Surveys." Mr. Beanland had surveyed the workings of two collieries, viz., the Grange and the Franklin, and he could only say that the surveys were found to be extremely accurate, and that Mr. Beanland had accomplished the object he wished to attain in those surveys. That gentleman had given the meridian of these two collieries, and as it was doubtful as to the needle being affected by the quantity of iron down a pit, it was satisfactory to know that they had a mode of checking it, as Mr. Beanland had informed him that he was prepared to furnish meridians to any pits in practice, and to do it on terms suitable to members of the Institute. As there were a large number of members present that day, Mr. Beanland would explain what had been done, for which purpose he had taken the liberty of asking him to attend, and to put down on paper what he proposed to do in carrying the matter into practical effect. That gentleman had, therefore, given him his paper; and although it was irregular to receive a paper from any person but a

member, yet, under the circumstances, he thought Mr. Beanland might be allowed to read it to the Institute.

This course having been freely assented to by the meeting,

Mr. BEANLAND read the paper "On Mining Surveys."

Mr. DUNN, at the termination of the paper, begged to ask Mr. Beanland what he did with the legs.

Mr. BEANLAND explained; but as the use of the legs is fully described in the paper, it is unnecessary to repeat his observations.

Mr. LONGRIDGE, however, doubted the accuracy of the bearings given by Mr. Beanland, and at the same time referred to some experiments of his own which he made by wires, and which he considered were more accurate than those made by Mr. Beanland.

After a brief explanation, which Mr. BEANLAND gave personally to Mr. LONGRIDGE, the subject dropped by the latter admitting that, although at first he doubted the accuracy of Mr. Beanland's experiments, yet, after the explanation given, he was convinced that the experiments could be done as accurately by that gentleman's system of survey as by any other he knew.

The PRESIDENT, addressing Mr. Beanland, said that the meeting was extremely obliged to him both for his paper and explanations.

Some conversation next ensued between the President and Mr. Elliot, who had just come into the meeting, relative to the propriety of postponing the discussion of his paper, when Mr. Elliot assented to it, principally on account of the absence of Mr. Thos. J. Taylor, who, he knew, could say a great deal upon the subject.

The PRESIDENT, in referring to the paper about to be read by Mr. Dunn, informed the meeting that it had previously been before the Council, who found that it contained a great deal of matter and statistical tables which had been previously printed. Now, he took the liberty of saying that it was not the province of the Council, or of the Institute, to republish anything, as what the Institute professed to do was to print original papers only. It, in consequence, occurred to the Council that only part of the paper ought to be read. He therefore asked Mr. Dunn, if he thought his paper would not be perfect without giving what had already been published concerning the Coal Trade of Belgium?

Mr. DUNN thought not, because it showed the statistics 10 years before the period he referred to: while his manuscript showed the quantities of coal raised since that period.

The PRESIDENT—But what the Institute required was subjects of a

scientific nature, and not the statistics showing the produce of coals either of Belgium or any other country. What they desired was information on scientific subjects. With these remarks Mr. Dunn might read part of his paper.

Mr. DUNN then read his paper on "The Coal Trade of Belgium."

Mr. ARMSTRONG next read his paper "On the Constitution and Action of the Chalybeate Mine Waters of Northumberland and Durham."

Mr. DAGLISH followed with his paper "On the Heating Power of Best and Small Coals."

Mr. BOYD, at the termination of the reading of the papers, begged to present the Institute with several volumes of books which belonged to his father, containing references to numerous papers read before the Members of the Literary and Philosophical Society of this town, including some by Mr. Winch, Mr. Hutton, Mr. George Stephenson, and other eminent gentlemen.

The PRESIDENT, on receiving the books in the name of the Institute, moved a vote of thanks to Mr. Boyd, which was passed unanimously.

The PRESIDENT, at the termination of the business, observed that what the Institute had accomplished during the past year was highly creditable to it, although he freely admitted that he was much disappointed by the deficient attendance of members, and especially of the young men of the Institute, who never seemed to give any countenance to their proceedings, as he seldom saw one at the monthly meetings. This, he thought, showed they did not adequately value the information they might derive by attending, and in hearing the papers read and the discussions upon them which ensued. He could assure them that, although it could not be expected they should possess the experience of older members, yet every encouragement would be held out to them if they attended, and the members would be glad to hear anything from any of them. As the day of meeting, however, had been changed, he hoped the attendance would improve in future.

Mr. DUNN begged, before the meeting separated, to move a vote of thanks to the President for his valuable services during the past year. Every one must acknowlege that his efforts and regular attendance had contributed greatly to the well being of the Institute.

Mr. HALL having seconded the motion, it was carried unanimously.

The PRESIDENT acknowledged the compliment paid to him, and said that his services were always at the command of the Institute, the success and future welfare of which he had much at heart. He certainly had

given his attention to everything connected with the Institute both within its doors and abroad, and he felt confident that since it had been established it had tended to raise the character of mining engineers in the estimation of the country. Let them only put their shoulders to the wheel and continue their efforts, they could not fail to raise the Institute into eminence in the literary and scientific world. One thing he would repeat, and that was, he trusted that in the ensuing year the younger members of the Institute would pay more attention to it and countenance its proceedings by their attendance.

The meeting then broke up.

ON MINING SURVEYS.

BY ARTHUR BEANLANDS.

The object of the present paper is to direct the attention of the members of the Institute to certain improvements which I have recently introduced in the practice of Mining Surveys.

It will not be necessary for me to say anything respecting the value and importance of accurate surveys of the workings of collieries and mines, and I think it will be generally admitted that a great proportion of colliery plans do not possess such a high degree of accuracy as might be desired. It seems also not unreasonable to suppose that the deficiency in this respect is owing, in a great measure, to a want of precision in the instruments and methods generally in use.

The plan which I have now to explain, is one which, I believe, will answer perfectly well in the great majority of collieries, if not in all. After much study of the subject, and actual trial of the method, I have been led to the conviction, that it possesses a high degree of accuracy for all practical purposes, and is decidedly superior to any other system which has come under my notice.

The leading feature of this plan consists in a method of fixing a bearing or meridian line at the bottom of the pit, the direction of which is determined, either with reference to the true meridian, or with respect to some line arbitrarily fixed on the surface. By this means the underground survey can be commenced, and carried forward to any extent, by means of the theodolite, and is properly connected with the surface, the whole process being thus effected without the aid of the magnetic compass.

This method of determining the bearing is my own invention, or, at least, I am not aware that the idea has ever been carried out before, or

has even occurred to any one else, though, of course, it is quite possible that I may not be the first person who has thought of such a plan.

The process, which I will now describe, is effected by means of a powerful transit instrument, mounted in the line of the shaft, either at the top or bottom as may be most convenient. For simplicity, I shall, in this description, suppose the instrument to be at the top of the shaft. It is fixed and properly adjusted on a very firm support, which must be so constructed as not to interrupt the view of the telescope, when pointed vertically down the shaft.

Two marks are then fixed at the bottom of the pit, as nearly as may be in the same vertical plane as the transit, so that each of them can be seen through the telescope, and appears nearly in the centre of the field of view. These marks are rendered visible at the top, by the light of a strong lamp reflected upwards, and are likewise so arranged that both can be seen by a theodolite placed at the bottom in a horizontal line with them. They are made as small as will allow of their being seen and observed by the transit at the top, and are of such form that they can be bisected by the wires with great precision.

The position of the instrument and of the marks is arranged to allow the latter to be as far apart as convenient, so that both marks can be seen through the telescope at the top.

If now, on pointing the instrument downwards, each of the marks appears exactly bisected by the middle wire, it is evident that the horizontal line, in which the marks are placed, coincides with the vertical plane of the instrument, and is, therefore, parallel to the position of the telescope when pointed horizontally. In this case, therefore, we have two lines, one at the top of the shaft, represented by the optical axis of the telescope when pointed horizontally; the other, the imaginary line joining the centres of the two illuminated marks at the bottom; and the bearing of the instrument being determined, either with reference to the meridian, or to some determinate line which can be connected with the surface survey, that of the line of direction of the marks below is ascertained at the same time.

This, however, is on the supposition, that each of the marks is seen precisely in the centre of the telescope. If this condition is not exactly fulfilled, the marks being a little out of the centre of the field of view, the apparent distance of each mark from the middle wire is accurately measured by a micrometer, or some other means, and from these distances, the angular deviation of the line of the marks from the plane of the

instrument is determined by calculation. Having found the amount of this deviation, the bearing of the line of marks is at once deduced from that of the instrument.

Hence, in this case also, as well as in the other, we have the means of connecting the underground survey with the surface plan.

It is necessary, in order to complete the process, that permanent marks should be fixed above and below, the marks aboveground being set out in some given direction with respect to the plane of the telescope; those below, with respect to the illuminated marks, which, as well as the instrument, must be removed from their places in the line of the shaft before the colliery can resume working.

Wherever the nature of the ground or erections on the surface admit of it, marks may be placed at once in the direction of the instrument above, being set out in any convenient positions, coinciding with the middle wire of the telescope. These permanent works should of course be placed so that one of them can be seen from the other, it is also desirable to have them conveniently placed for the commencement of the surface survey.

Where, however, it is not practicable to set out a line in the direction of the transit, owing to obstructions, some other direction must be taken, one mark being fixed in the line of the instrument, and the other at any point at a convenient distance, and visible from the first. The direction of the permanent line will, of course, be determined with respect to that of the transit, by setting up the theodolite at the nearer station, and measuring the angle between the direction of the transit, and that of the further station.

The permanent marks at the bottom of the pit are fixed in like manner, and their direction determined from that of the illuminated marks, by the aid of the theodolite, which is placed at some point near the shaft, in the line of the illuminated marks, and from which a more distant point can be seen. A permanent mark is then fixed at the place occupied by the theodolite, and another at the more distant point referred to, which may be chosen convenient for the commencement of the underground survey.

I have thus endeavoured to explain, somewhat briefly, but I trust with sufficient distinctness, the method by which the underground survey is connected with the surface. It will scarcely be necessary for me to observe that the whole process is one requiring great care, and an intimate acquaintance with the use and manipulation of the instruments, such as can scarcely be acquired without considerable experience. With pro-

per management, however, and a transit of sufficient size and power, I believe the bearing may generally be fixed at the bottom of the pit without any error exceeding one minute of arc, a degree of precision amply sufficient for all practical purposes.

I shall merely add a few remarks respecting the mode of carrying forward the underground survey with the theodolite.

As the workings of collieries are frequently very extensive, and cannot be surveyed without a great number of lines and angles, the stations often occurring at very short intervals, it is obviously a matter of great importance that we should, as far as possible, avoid committing errors in the process of changing the instrument from one station to another. This is effected very completely by the following method pointed out in "Williams' Practical Geodesy." Three pairs of legs are provided for the theodolite, and each of them is so contrived that a lamp or some other convenient object can be placed upon it exactly in the position occupied by the centre of the instrument. Thus, on removing the theodolite forward, the lamp in advance and the instrument are made to change places without disturbing the legs, two pairs being always kept fixed while the instrument is changed, and the third pair moved from the back station to the new one in advance. By this means the errors to which I have referred may be rendered almost insensible.

I have thought it proper to mention this mode of using the theodolite, as I believe it is not very generally understood, although it is by no means new. I consider it of great importance in practice, and have proved the value of it by actual trial. Without this improvement, the utility of the instrument is very much lessened in underground surveys, both with respect to accuracy and convenience; but with this contrivance, and the usual precautions against error, which will at once suggest themselves to every one familiar with the instrument and acquainted with the elementary principles of geometry, I consider that for the purposes of an under-ground survey the theodolite may be regarded as perfect.

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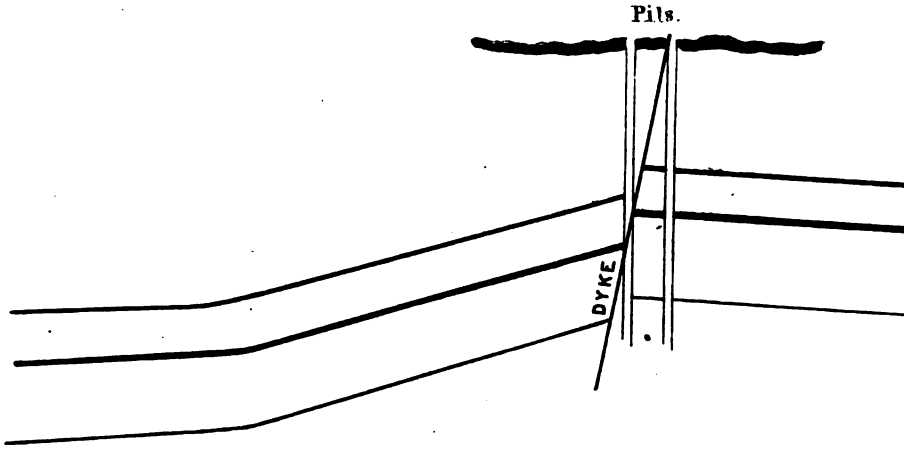


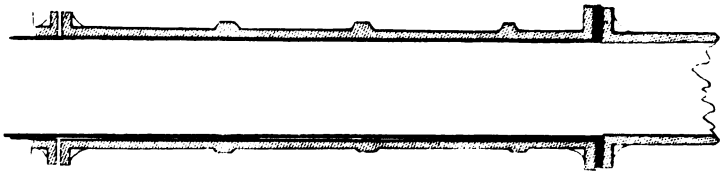


Fig. 1

IELD, *FROM NORTH TO SOUTH.*

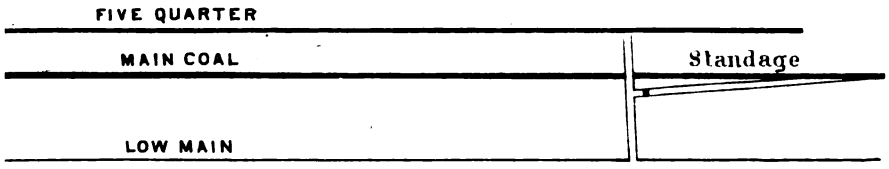
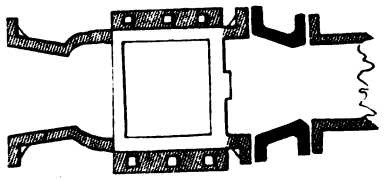


Fig. 5.



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OF THE CONSTITUTION AND ACTION

OF THE

CHALYBEATE MINE WATERS

OF

NORTHUMBERLAND AND DURHAM.

BY WM. ARMSTRONG, JUN.

The mine waters of Northumberland and Durham may be divided into three classes:—

1. The saline.
2. Water with no predominant characteristic.
3. The chalybeate, containing salts of iron in solution.

In the first class—the salts, principally chloride of sodium and calcium, are probably derived by percolation from the sea or river through the numerous cross dykes which traverse the district, or through the fissured limestone of the magnesian formation, where this rock is the overlying cover. Hebburn, Jarrow, Harton, Seaton, and Hartley may be adduced as examples of this class of mine water, and exhibiting all combinations of the salts, and in every degree of intensity. Frequently with the saline there are combinations of iron salts, depending more or less upon the conditions of the coal seams and their accompanying strata.

In the second class—the mine water acquires but few impurities, the roof and thill of the seam being little intermixed with foreign matter, and except as to its quantity, which is sometimes formidable, presents little difficulty in its treatment.

And in the third class—the mine water, from the roof being frangible

and the thill soft, both containing pyrites in greater or less abundance, and associated with aluminous shales, speedily acquires, under favourable conditions, the distinguishing character of this class.

The collieries working the Five-Quarter seam in the Hartlepool district exhibit this water most distinctively, for except the aluminous and earthy salts, which replace each other, and these in inconsiderable quantities, iron is the principal constituent of the water.

I have selected the third division, the Chalybeate water, for illustration in this paper, from having had to contend with an example presenting very corrosive properties, such as I feel assured has never been met with in such quantity, nor continued over so long a period, in any colliery in our Northern district.

I will first detail the circumstances under which the water acquired its peculiar constitution, arising principally from the local position of the coal field, and the working shafts.

Second,—The different mechanical resources and changes which its injury to the pumping apparatus of the colliery necessitated, and

Lastly,—A few of the chemical results arising out of its examination.

The Wingate Grange coal field has a very peculiar conformation, being traversed midway by a dyke, separating the field into nearly equal portions, each portion dipping from the dyke, the one to the north, the other to the south boundary of the estate. The two shafts were unfortunately sunk upon the summit level of the property, one on either side of the dyke. In the exploring of the coal field, and until the pumping engine could be rendered available, a very considerable acreage of the Five-Quarter seam, the first in the series, was gone over, leaving the pillars, before the underlevel communication from the full dip of the estate was made with the engine pit, and the necessary standage was prepared.—*Vide Section A.*

The pumping engine, of 200-horse power, worked three lifts of pumps. One Set, the Lowest, fifty three fathoms long, attached to the outside of the beam—the two others, about thirty-two fathoms each—the Middle Set, worked by a diagonal spear and quadrant in the usual way—the High Set, attached to an auxiliary beam.

The working barrels of all the Sets being eighteen inches in diameter, with a six feet stroke, the buckets and other appendages fitted in the ordinary manner.

The Three-Quarter coal immediately overlies the 'Five-Quarter,' with

numerous interstratified beds of soft aluminous shale, largely impregnated with iron pyrites, and forming the roof of the working seam, and, from its loose and frangible substance readily falling on the withdrawal of the supporting timber. In addition, the thill of the coal and a portion of the seam itself are largely mixed with the same pyrites. A few fathoms above the Three-Quarter coal is the 'Yellow Sand,' very capricious in its thickness and consistency, and containing considerable feeders of water, in some measure depending upon the constitution of the stratum itself. At the working pits in the middle of the estate the Sand is hard and thin, and the feeders did not exceed 600 gallons per minute, whereas to the north-east of the same property, and at the distance of a mile, the Sand had increased to thirty-six feet in thickness, the particles so loosely cohering as to be readily separated on the slightest pressure, and containing so much water as to baffle the united exertions of two large engines, which, at one time, delivered to the surface 1,800 gallons per minute, and except by way of inference, afforded no certain datum as to the magnitude of the feeders which would have to be encountered in perforating the sand.

With so formidable an antagonist as the 'Sand' water, it became important to provide a considerable standage reservoir, and to facilitate this, and to hasten the time for commencing the removal of the pillars, a drowned drift was made in the 'Low Main' seam, being well suited for the purpose, and thus connecting the pumping engine with the standage excavated in the 'Main Coal,' to the full dip, and next the north boundary of the property.

A metal Dam, consisting of segments in the usual way, was inserted in the underlevel drift, so as to shut off all communication with the engine shaft, during the temporary and inevitable delays in the necessary changes of the working parts of the pumps.

As soon as this was accomplished, the first pillars were removed in the 'Five-Quarter,' and the falls in the strata soon communicated with the Sand feeders which had to traverse the old pillars before filling into the Main coal standage, and from thence by the 'Low Main' home to the pump.

The feeder at first exceeded 500 gallons per minute, and for some months was kept under perfect control by the engine, and pillar working being extended, little abatement was noticed in its quantity.

In November, 1844, the water was observed to have acquired a caustic and styptic taste, and gradually an ochery deposit was left in its channel, which increased with time, and although discharged transparent from the

pump rapidly underwent a chemical change, its iron being deposited in such considerable quantities as to render the water turbid.

Beyond encrusting the pumps and spears with a thick sediment no other injury was apprehended, but it was observed that the colour of the water gradually deepened, the deposit was more rapid, and acquired a solidity frequently observable in boiler sediments.

It soon after began to attack the pumps and iron work; the metal of the pumps was rapidly converted into a kind of graphite, and rendered so soft as to be easily cut with a knife; the iron work was corroded, and the leather of the buckets and clacks rendered brittle and black from a chemical action of the sulphate of iron with the gallic acid of the leather. It was further obvious that free acid of some kind must be present, from its rapidly reddening litmus paper and the sharply acidulated taste the water had acquired.

The first step was to substitute brass, for the metal buckets and clacks, and to introduce a second or twin set into the bottom, so as to alternate the set in use, with a hope that the evil was but temporary.

The clack seats of the Low sets first failed; the sets were drawn, and metal pieces again introduced with a provision for drop clacks in the event of further interference. At the same time we replaced both bucket trees, having been much injured, and the pumping was resumed.

The working barrels of the Low sets next failed, and both were again drawn, and brass chambers $\frac{3}{4}$ inch thick introduced in the ordinary way, filled up behind with cement. The High and Middle set working barrels were likewise drawn in November, 1845, and both brass chambered after the same fashion as the Low sets.

Meanwhile, from the suspension of the engine during these changes, the water had filled the lower workings of the colliery, and from its now occupying a larger area, soon acquired a higher corrosive action than before, for in April, 1846, we were again compelled to draw the High and Middle sets, and replace the working barrels which had been chambered with brass in the November of the preceding year,—the iron cement having been eaten out, the chambers loosened, and the metal case worn through. The plan for chambering the barrels was altered, the metal case having been turned out, and the brass lining fitted tight,—brought under the lower flange of the barrel forming part of the flange,—the brass lining being wedged close at the top with wood wedges.—*Vide Fig.* 1.

All the spear plates, bolts, and cross bars of the doors were now to be renewed, and the action upon the bottom rods and larger pieces was soon developed.

The two new clack pieces of the Low twin sets were next destroyed, large cavities having been formed from the eddying of the water on the sides of the clack, assisted by the unequal quality of the metal and the difficulty of avoiding air holes in such heavy castings,—these latter considerably facilitating the action of the water. The new bucket trees of these sets were also holed through at the doorways and plugged, and the flange holes of the common pumps, the lowest in the set, were so enlarged from the water passing through the joints as to necessitate the drawing of these sets again. This was accomplished in August, 1846, and the brass chambered working barrels were found so corroded and worn, the metal cases having been perforated in many places from the joint action of the water inside and outside the barrels, as to render them entirely useless.

All hope of combating our enemy with ordinary mechanical appliances was now surrendered, as the feeder continued undiminished, and from the larger area of the colliery workings now under water, a continued and increased decomposition was kept up.

At an early stage of the struggle, when the destructive action of the water was first observed, various authorities were consulted for remedies, and to Dr. Richardson, of Newcastle, we were particularly indebted for much professional aid.

His analysis of the water when at its worst stage was:—

In 1000 parts, ...	Sulphate of Iron	3·51
	Sulphate of Alumina	·33
	Sulphate of Lime.....	1·89
	Free Sulphuric Acid	1·64
	Chloride of Magnesium	Trace
	Chloride of Sodium	Trace

It will be observed that the *rationale* of the mischief was at once apparent, for the *free* sulphuric acid in the large per centage shown in the analysis sufficiently accounted for the rapid decomposition of the metal and iron of the pump, aided as the action was by so considerable a mechanical pressure.

It was at first advised that the acid should be neutralized by any of the Carbonates of Lime. Assuming however, the quantity pumped at 450 gallons per minute, the weight of free sulphuric acid in that quantity would be 7·38lbs., requiring for its saturation 9·22lbs. of limestone or chalk per minute, or, in round numbers, 5 cwt. per hour. It was at once obvious that this large quantity of 6 tons per day of chalk, under the peculiar circumstances in which we were placed, was incapable of manage-

ment, for it involved the removal of this weight of Sulphate of Lime, and the renewal of the Carbonate every 24 hours, and we enjoyed few opportunities of accomplishing this with any regularity, being ultimately shut out from all access to the working pieces of the Low sets from the metal dams having been eaten through, and this source of protection in the isolation of our shaft destroyed.

Paints and varnishes of various kinds had been used for protecting the iron work, all of which had proved ineffectual, and it was in this stage of our proceedings, when the chalk had failed us, and the Low sets had been drawn, and in the mutilated condition before referred to, that we had recourse to Faraday and other high authorities.

Copper and Brass were both vulnerable—Glass pipes and Wooden pumps were suggested—Lead and then Antimony or Tin, and their alloys in different proportions, such as are used in alum works where the liquor is intensely acid, and with complete success, and the pumps lined with sheet lead, as in the same manufacture, but all gave way before the practical difficulty of their application on the great scale.

I had suggested galvanic agency to Dr. Richardson, from some experiments I had seen in Edinburgh, by introducing at intervals short doorways, with internal zinc rings for the protection of the metal; and as a last resource for the working barrels, different alloys of tin, lead, and antimony, which were known in more highly acidulated water to withstand the acid, were subjected to experiment as to their ability to bear the necessary pressure of the column.

A pump two feet long was cast of an alloy of equal parts of Lead and Tin, and subjected to a pressure of sixty tons, without producing any appreciable alteration in either its length or diameter.

With 3-5ths Lead and 2-5ths Tin, a cylinder one inch long and one inch diameter gave no appreciable effect under a pressure of 3925lbs. per square inch, but with a pressure of 8471lbs. per square inch, it was reduced in length to $\frac{6}{8}\frac{1}{4}$ inch, and increased to $1\frac{3}{6}\frac{1}{4}$ in diameter.

With 2-5ths Lead and 3-5ths Tin, a cylinder of the same dimensions was reduced with a pressure of 9470lbs. per square inch to $\frac{6}{8}\frac{4}{4}$ inch, and its diameter enlarged to $1\frac{1}{6}\frac{1}{4}$ inch.

With $\frac{1}{2}$ Lead and $\frac{1}{2}$ Tin, a cylinder of the same size was reduced under the same weight, to $\frac{6}{8}\frac{1}{4}$ inch, and enlarged to a diameter of $1\frac{3}{6}\frac{1}{4}$ inch.

Many other experiments were made with different alloys, all showing that composition might be obtained of sufficient strength and tenacity to withstand the weight of the column, and yet be invulnerable to the action of the acid.

Much, however, of the reasoning derived from experiment in the laboratory was falsified in the pit, and unexpected actions upon alloys which had indicated no trace of interference under simple immersion in acid solutions of much greater strength, assumed new conditions when subjected to a pressure of a column of 135lbs. per square inch, and it was highly probable that, independent of electric currents arising from so active a chemical decomposition, galvanic action was also superinduced when different substances were brought into contact and subjected to a pressure under saline matter and acid, so fully calculated to generate the new agency. Whether or not this formed an element in our difficulty we could not determine, but the bucket and clack falls, with the rivets made from those suggested alloys, in different proportions, were all more or less affected, and as soon as the smallest perforation had been worked, the further corrosion went on, in a fast accelerating ratio, until we had almost despaired of a remedy.

In this stage of our work, having drawn in August, 1846, the twin Low sets formerly referred to as having had the brass chambers destroyed, we substituted in one of the sets a solid Bell Metal working barrel, composed of an alloy of 2½oz. of Tin to 1lb. of Copper, a compound which Messrs. Abbott had found, after much experience in mineral waters, best resisted the action of acids—and replaced the other working barrel with a brass chamber fitted in, (as shown in *Fig.* 1)—and at the same time small chambers were introduced at intervals of 5 fathoms (forming part of the set of pumps to which the bell metal chamber was attached), within which small chambers, three zinc rings were wedged back in contact with the metal sides of the chamber, and so in point of fact to connect the entire set into a galvanic battery. Doors were attached to each chamber to give access for the renewal of the zinc rings.—*Fig.* 2.

The metal clack piece was also replaced by a short one (*see Fig.* 3) of Bell Metal, of the same composition as the working barrel, and having no door, we got rid of this difficulty. Clack shells and falls were also substituted of the same metal.

A composition, suggested by a German chemist, (which had been largely employed in Wales, where the metal of an air pump was exposed to steam mixed with sulphuric and sulphurous acid vapours,) consisting of 40 parts of coal pitch, 1 part of fluid caoutchouc, and intimately mixed with 6 parts of finely powdered red lead, we found the most efficient coating—and the swords, bottom rods, plates, and bolts were smeared

with it from time to time—Bees' wax was afterwards added to improve its consistency.

After all these preparations we conceived we had completely surmounted our difficulty, having secured the working pieces of the pump of the most stubborn metal, and neutralized, we hoped, the further action upon the pumps and iron work.

The protection of the zinc rings appeared at first to be perfect, and as long as we could continue the contact of the two metals the pumps remained unscathed; but it soon became obvious that the cost of the renewal of the rings, (for their oxidation went on very rapidly,) and the stoppages occasioned thereby generated a larger evil than was cured—the limit of the protective power of zinc in metallic contact with iron being between $\frac{1}{64}$th and $\frac{1}{128}$th of the surface of the latter, and from the friction of the water upon the spear plates and bottom rods, the composition was washed off, and the destruction of these still went on so quickly as to render all our precautions nugatory.

There was but one alternative which suggested itself to save the colliery, for it was now nearly filled with water—to shorten the column of the Low set and divide it into two sets—for we had observed that the corrosive action on the iron and metal in the High and Middle sets was within manageable limits, which we attributed entirely to the lesser pressure of the column.

Formidable as the change was, it was completed in 1846, and it was soon apparent that two sets of working parts were easier to uphold, from the diminished pressure of the divided column, than the longer column as a single pump.

To assist in ridding the colliery of the accumulated water, we attached two 350 gallon cisterns to one of the coal machines, and notwithstanding the unavoidable accidents from the fluctuating level of the water as it was gradually depressed, and the rapid corrosion of the chains, valves, &c., we at length (after several changes in the pumps, &c., which it would be tedious to repeat), in the summer of 1847, reduced the dead water once more to the north standage.

Single drifts were now made through the coal pillars, and the water limited to one or two channels, and the feeder having taken off to 300 gallons per minute, we were enabled to dilute it with fresh water, and from this weakened mixture, and the still further dilution as the pyrites of the single channel beds were exhausted, we gradually got the water

under complete control, and although now requiring constant vigilance, and attended with rather more than the ordinary cost of pumping water, it has fallen within the category of those mining necessities which are daily to be encountered and overcome in the working of our collieries.

Such, in its most aggravated form, generated under circumstances seldom or never in co-operation, was the action of this Chalybeate water upon the pumping apparatus of the Wingate Grange Colliery, and in all, or many of the Five-Quarter seams in working in the Hartlepool district a similar action, at some time or other, but much modified in its intensity, has similarly characterized this class of mine water.

The outlay in wages and apparatus alone in the year 1846 was £3,600, which will afford some idea of the magnitude of the evil.

The Chemical changes are exceedingly interesting, and present many points for consideration in connexion with our boilers, and the changes superinduced upon the tub casing of our deeper pits.

Iron, when covered with water, is converted first into a protoxide, or ferrous oxide, and ultimately into ferric or peroxide, by taking up the oxygen which the water absorbs from the air, and in this state of oxide, combining with a portion of water, forming the hydrated peroxide.

The purest iron is oxidized most easily, and hard cast iron resists the action longest. In our boilers and tubbing, where exposed to water, we have three changes at least. First into the protoxide, Fe. 0—then the black oxide, a compound of the former with the peroxide, in various proportions, generally $Fe.^3\ 0^4$—and, lastly, into the per or sesqui-oxide—or $Fe.^2\ 0^3$. But the changes do not stop here as is generally understood, for immediately that the peroxide is formed, it induces the iron again to decompose the water, and again to form the protoxide, with which the peroxide unites, to become the black oxide, and no sooner has it acquired this state than by fresh absorption of oxygen it passes into the peroxide—again to undergo and set up the same series of changes, and thus the process of destruction is hastened—precisely as in the manufacture of the green vitriol of commerce, iron is added from time to time, to furnish material for the successive oxide changes.

It is assumed, ordinarily, that the peroxide will itself form a crust, and thus protect the iron from the further action of the water; but this is not so; the decomposition being found to be powerfully assisted by the continued action of the peroxide upon the water, abstracting the oxygen necessary for the curious changes here indicated.

With the salts of iron, however, the waste is still further accelerated, and, there being little mine water quite pure, we have only to analyse it to ascertain what constituent it is, that adds to its ordinary decomposing power.

In many of the coal seams, particularly in the Five-Quarter seam of the Hartlepool district, there is abundance of the bi-sulphide or sulphuret of iron in combination with the coals and shales. In the presence of moisture the iron becomes the protoxide, and the sulphur, sulphuric acid forming, when combined, the protosulphate of iron or the green vitriol of commerce,—and this again passes readily into the yellowish brown powder the sulphate of the peroxide, which is insoluble in water,—and it is in these changes that the evolution of heat takes place which gives rise to those numerous cases of spontaneous combustion so common in the coarser coals of our Midland counties.

The technical reason for the sudden and increasing ochery deposit in this and other water having a similar constitution is, that, forming with the sulphuret of iron, hydro-sulphuric acid, and protoxide of iron, which, by the further decomposition of the water, yields oxygen for the peroxide—if there be no excess of acid present to hold the solution of the peroxide first produced in solution, part of it is deposited in the ochery form with which we are so familiar, and so the process continues with the successive productions of the per salt.

Light has been found to exercise a singular agency on this deposit. When in the pit, and, up to the period of its delivery from the pumps, the transparency of the water is considerable and the deposit a work of slow process; immediately on its exposure to the sunlight the oxidation is rapidly stimulated, and the water speedily acquires the transitions of colour, as the protoxide gradually acquires its oxygen and is deposited as the per salt.

These are the ordinary chemical changes produced when iron and sulphur are brought into contact with water, and its destructive action when so impregnated is soon exhibited upon all iron and metal, but more particularly on boilers where the action is so much assisted by the heated water, and when it is remembered, that it is precisely those qualities of iron which are finest and most largely combined with carbon that yield most easily to oxidation, it becomes all the more necessary to exclude, as far as practicable, any water, which in any way has become deteriorated by holding iron in solution, or the still more pernicious drainage of refuse heaps. The tests are most delicate, and easy of application.

In the Wingate water, however, pressure became a most important

element, and gave to the corrosive action of the water an intensity which would have been otherwise unaccountable.

It is more difficult to account satisfactorily for the gradual change in the chemical constitution of the metal of the pumps. Below the crust of oxide there is found a considerable softening of the metal, which, reaching some distance into its substance, is capable of being cut with a knife. This peculiar transformation is more or less perceived in all old pumps, but more particularly in those exposed to the long and repeated action of iron or saline water.

We know that dilute hydrochloric acid will dissolve cast iron, which leaves a copious black carbonaceous deposit as a residue, a kind of graphite in fact—insoluble in acids. We know that cast iron, if long immersed in sea water, is converted into a substance like plumbago, and even in fresh water, is converted by the carbonic acid of the air, although very slowly, and with deposition of rust, into the same graphitic substance, and according to Dumas, this is a mixture of graphite and a combination of carbon and iron, but in very uncertain proportions—probably $Fe. C^3$, with from 82 to 94 per cent. of per oxide. The mass is magnetic, and oxidizes upon exposure to the air.

I think it likely that the sulphurous acid gas from our ventilating furnaces, associated with the carbonic acid of the smoke, has a very analogous effect, and over a long time, produces upon the surface, and within the substance of our pumps and tubbing, that graphitic compound of which we have such abundant experience in our upcast shafts, and which so effectually destroys it as a means of resisting pressure.

It is suggested that it is well worthy the attention of the Institute to order a scientific analysis of the changes thus brought about in the surface substance of our metal tubbing, with a view to some protective agency being devised to counteract this corroding action upon a casing, the fixing of which has been attended with so extraordinary an outlay, and whose sudden and unexpected fracture, so frequent in late years, from the higher temperature our upcast shafts have acquired, has so materially added to the hazard, and enhanced the difficulties of Coal mining.

ON THE RELATIVE

HEATING AND ECONOMIC VALUES

OF

ROUND AND SMALL COALS.

BY JOHN DAGLISH.

The following calculations are deduced from a series of experiments made at an extensive mill, in 1854. From the high price of fuel at the mill, enhanced by long carriage, great economy was observed in its use; the experiments were made with considerable quantities, viz., 100 tons of each description of coal, and every precaution was taken to insure accuracy.

The fuel experimented upon was an open burning steam coal (Hartley), of three qualities, viz., *round*, *unscreened*, and *beans*.

The *round* were large, clean, of excellent quality, and well screened over bars ½ inch apart. And the quantity consumed, per shift of 8 hours, was 4 tons 12 cwt.

The *unscreened* were made by mixing equal quantities of the above with the small that passed through the bars, *i.e.*, equal proportions of *round* and *small*. The quantity consumed, per shift of 8 hours, was 5 tons 4 cwt.

The *beans* were made by passing the *small* (which were screened from the *round* through ½ inch bars), over ¼ inch apart wire gauze; they were not a good sample, being damp and much mixed with small stones, from the nature of the mine. The quantity consumed, per shift of 8 hours, was 5 tons 19 cwt.

Trial was also made with the *small* coals, but even with extreme firing the steam could not be kept at the requisite pressure, and the experiment was abandoned.

Table I.—*Equivalent heating quantities,* being the actual quantities of different kinds of coal consumed per shift of 8 hours, by 2 tubular cylindrical boilers, keeping the steam at a uniform pressure of 13lbs. per inch, as indicated by a mercurial gauge in the boiler house:—

	Tons.	Cwt.	
Round	4	12	or 1·000
Unscreened	5	4	1·130
Beans	5	19	1·293

Table II.—And the *heating values* being inversely in proportion to the quantities consumed,

Round	1·000
Unscreened	·884
Beans	·773

*At the date of these experiments the value at the pit of the different kinds of coal may be taken at

	s.	d.		s.	d.	
Round	18	6	per chal., or	7	0	per ton.
Unscreened	13	3	„	5	0	„
Beans	8	0	„	3	0	„
Small	5	3	„	2	0	„

Table III.—Therefore, the *actual cost* at the pit, of *equivalent heating quantities,* will be

	s.	d.					
Round	7	0	×	1·000	=	7·000	or 1·000
Unscreened	5	0	×	1·130	=	5·650	„ ·807
Beans	3	0	×	1·293	=	3·879	„ ·554

Table IV.—And the *economic value* at the pit being inversely in proportion to the *actual cost of equivalent heating quantities.*

Round	1·000
Unscreened	1·239
Beans	1·804

Thus *beans* are nearly twice (1·8) as economical to the consumer as *round* at the pit.

But the cost of carriage, &c., after leaving the pit being a constant or fixed charge alike on all qualities of coal, there must be some point of distance from the pit at which the *economic value* of any two qualities will be equal.

* These proportions have been submitted to the manager of large iron works in this neighbourhood, and he finds them approximate nearly to his experience.

And, on the foregoing data, it will be found by calculation, that when the cost of carriage, &c., amounts to 11s. per ton, the *economic value* of *round*, *unscreened*, and *bean coals* are about equal.

TABLE V.

Equivalent Heating Quantities.		Original Cost at Pit.	Cost of Carriage.	Economic Value.
1	Ton of Round	× (7s.	+ 11s.)	= 18·00
1·130	" Unscreened	× (5s.	+ 11s.)	= 18·08
1·293	" Beans	× (3s.	+ 11s.)	= 18·10

It may be added, however, that there are other points to be taken into consideration together with the above, which bear favourably on the use of round coals; the inferior qualities of coal being intermixed with stones and other foreign matter are more injurious to boilers and fireplaces, and leave a greater bulk of ash and clinker. Therefore, the actual point where the economic values of these qualities of coal are equal, may be taken rather below that as calculated above, especially with engines having limited boiler power, or where a rapid generation of steam is required.

REMARKS

ON THE

STATE OF BELGIUM AND FRANCE,

IN RESPECT TO THE

PRODUCTION OF COAL

AS COMPARED WITH

ENGLAND AND SCOTLAND.

BY M. DUNN,
GOVERNMENT MINE INSPECTOR.

For many years the country around Paris drew its supply of coal by means of canals from the coal mines of Belgium and the neighbouring coal field of Valenciennes, whilst Belgium also exported considerably to the Mediterranean, Holland, and Prussia. To encourage this trade, and as a boon to Belgium, the import duties into France were highly favoured, and would, in all probability, have continued so for many years to come had the raising of coals in Belgium kept pace with the increased consumption, and especially had the Belgian collieries spiritedly carried out the progressive improvements of England, and thereby diminished the cost price, whilst arrangements were making for commanding the deep mines and for an increased production similar to what has taken place in England and Scotland.

That such improvement of system and consequent increase of production has not materially taken place will, I think, be shown in the following pages, but rather that the short supply, overtaken by increased demand, has produced prices so high as to place these collieries out of the

power of competing for the supply of Paris, which has suggested a policy to the French Government of equalizing the duties and of encouraging the importation of English coal.

It becomes, therefore, an important question why such a state of things has overtaken Belgium—that instead of largely exporting coals, the wants of the country seem to demand a remission of import duties and to encourage a supply of coal from England?

It will not be alleged that such falling off arises from the exhaustion of the mines, but rather from a deficiency of the means of attaining the numerous beds of coal lying at unusual depths, which, of course, require a system of ventilation and enlarged engine power beyond the routine of even the deepest collieries in the country.

I am tempted to write upon this subject, because in the month of September, 1843, I visited the deepest district in Hainault around Mons, examined the mode of working, and had access to the accounts of several of the collieries, with a view of drawing a comparison between the practice of Belgium and that of England and Scotland.

Soon after my return from Belgium I published "*A History of the North of England Coal Trade*," in which work I introduced the subject of the Belgian collieries and their statistics. I will, therefore, first take the liberty of extracting a few remarks from the said work regarding their position in 1838, which led me to conclude that the then principles of mining were, in many respects, faulty, and could only be upheld by high prices; which high prices would necessarily lead to the exclusion of the Belgian coals from the Parisian market if ever a relaxation of the import duties upon English coals took place.

This event has now every appearance of being realized, and, in consequence, powerful companies are establishing in France and England, having for their object the building of iron screw steamers, to carry 600 or 800 tons each, requiring a very light draught of water, with a view of navigating the Seine up to the quays of Paris, or the transference of the coals into railway waggons at Rouen, Havre, or Dieppe.

Whilst in Belgium I was favoured with some of the official reports of the state of the mines, ending 1838, and since then I have received another official report, by the Minister of Public Works, M. Em Van Horebeke, published on the 20th December, 1854, which report embraces the statistics from 1841 to 1850 inclusive.

The official documents, therefore, in addition to my own examinations, enable me to form a tolerable judgment of the matter in question.

It is worthy of remark that the coal seams of Belgium are much thinner and more numerous than those of Great Britain, and are generally accompanied by shales and soft metals, to which circumstance may be attributed the remarkable absence of water, which is particularly exemplified in the Hainault district, by the fact that whilst the coal engines are 145 in number and possessing 3881 horse-power, the pumping engines are only 58, amounting in horse-power to 5279, although many of the mines are upwards of 150 fathoms in depth.

The coal-field of Belgium is connected with that of the north of France in the neighbourhood of Valenciennes, Conde, Mons, Namur, Liege, and a considerable portion of the Duchy of Limburg, towards the Rhine, and contains, in the centre of the Basin, no less than 134 workable seams of coal. The length of the Basin from East to West is about 40 miles, (22 killometres* per mile,) with a mean width from North to South of about 8 miles, occupying a surface of about 326 square miles in Belgium.

In the neighbourhood of Mons, 114 seams are well known, amongst which, the group Flenu, containing 32 beds, is the richest.

The first steam engine for raising water was erected in the neighbourhood of Charleroi, in the year 1725, by a person of the name of Mesonne; and in the district of Mons, in the year 1735, by a person of the name of Goffint, both belonging to Liege. The working of coal at Liege is known to have commenced about the end of the 12th century, the first steam engine for raising water being in the year 1723, which had increased to four in 1767.

In the year 1838 the relative state of coal mines in France, Belgium, and Prussia, was as follows:—

	Working Pits.	Tons.	No. of People.	Value. Francs.
France	157 ..	3,113,300 ..	23,751 ..	29,078,083
Belgium.....	480 ..	3,260,271 ..	37,171	
Prussia	628 ..	2,308,368 .	17,884 ..	16,121,160

In the following years the coal mining position of Great Britain, France, and Belgium, was,—

	Proportion of Surface Coal Mining Area. Hectare.		Year.	Tons.
Great Britain...	1,172,000	= $\frac{1}{20}$th ..	1835 ..	24,000,000
France.....	252,000	= $\frac{1}{2\frac{1}{10}}$th ..	1838 ..	2,944,694
Belgium	134,000	= $\frac{1}{2\frac{1}{2}}$nd ..	1838 ..	3,260,271
Prussia	....	..	1838 ..	2,308,368

* The metre, 39·371 inches; killometre, 1090 sq. yards; hectare, 11,960 sq. yards.

Price of Belgian coal, Flenu, per ton at pits in 1838, was

Gaillettes. Francs.		Gailletteru.		Small.
20·40	..	16·80	..	7·20

The number of working pits in Belgium in 1838 were 480, and 172 in course of sinking. The coal mines belong to the Government, and the custom has been to let so many seams to one person, and so many other seams to others, giving power of access through each other's holdings, which custom is producing great inconvenience, and which will take a long series of years to counteract.

The exclusion of English coal by Napoleon I., and the encampment of the grand army at Boulogne in 1803-4-5, preparatory to an invasion of England, gave a great impulse to the Belgian coal trade, and, in consequence, numerous companies arose, and obtained great privileges from the Government, but which, in due time, caused a serious reaction, similar to the Joint Stock Companies in England. This especially happened in the year 1834.

According to M. E. Tennant, M.P., (who visited this country in 1842), between the years 1833 and 1838 not less than 150 Joint Stock Companies, called "*Societé Anonyme*," were formed for the purpose of working the mines, carrying on glass works, sugar refineries, &c., and that not less than 15 millions sterling of capital were expended in these objects. Since 1830, capital, amounting to 4 millions sterling, was raised in Belgium for the purpose of working the coal mines.

In 1838, the thirst for speculation had reached its maximum; the exorbitant premiums upon collieries and coal leases, which had hitherto been paid were at an end, and a retrograde movement took place.

The extent to which these speculations was carried on, will be estimated by the statement, that in the year 1838, the "Civil Societies" possessed 224 out of the 307 collieries of the Belgian kingdom.

Forty-three mines had been acquired wholly or in part by "Anonymous Societies," in consequence of subscribed capital being brought in; and the following will show the number of pits which they established up to 1838, and the quantity of coal which they raised for sale.

The number of Mines acquired in which anonymous societies were interested were 83, having 271 working pits, raising a total of 1,285,427 tons of coals.

The Mines remaining in the hands of individuals or ancient societies were in the same year 224, having 389 working pits, raising a total of 1,974,844 tons of coals.

Coals from the province of Hainault have, for their principal outlet,

France and the provinces of the two Flanders, Antwerp, Brabant, and Namur. The produce is conveyed by the canal of Mons to Conde, the Escaut, and the canal of St. Quentin—by the canal of Mons to Antoing, to Escaut, and the Lys—by the Dondre—by the canal of Charleroi to Brussels—by the Sambre (made navigable,) and the Meuse—by the Sambre and Oise—and also, by a great number of paved roads which connect the mines with the surrounding towns and villages.

The quantity of coal conveyed by the rivers, in the neighbourhood of Mons, into Flanders, Holland, and France, during 1838 was 1,198,300 tons.

The classification of these numerous seams is in some respects hypothetical, as they are traced from their respective outcrops and the successive sinkings upon some or others of them; but the theory of the aforesaid number of seams is universally admitted by the mining engineers. The depth of the pits is exceedingly variable. I descended some of them in the Mons district, 180 fathoms in depth, which were working *the upper or Flenu beds;* and as these collieries were known to be situated very near to the bottom of the basin, it was computed, that a further sinking of 900 fathoms would be required to command the lowest coal. The western coal field is overlaid by a formation of chalk and flint, varying according to the sinkings, from 20 to 140 yards in thickness, and giving out water; but the coal stratification is remarkably free from water, and from the information I received, it is, generally speaking, composed of argillaceous strata.

The price of coals, in 1838, was higher than at any previous period, and had been gradually increasing during the preceding nine years, at the rate of 5 per cent. per annum. The price varied, according to quality, and the mode in which they are prepared for market, from 7s. to 20s. 6d. per ton. The English ton is 2,240lbs.

These prices were received at the canals, and the conveyances from the collieries may be taken at 9d. to 1s. per ton.

The quantity of coals raised in 1838, amounted to 3,685,402 tons, and the quantity exported to France and other countries was 775,000 tons.

The royalty over all the mines belongs to the government, who regulate the rent according to general policy. The law of the 24th of April, 1810, fixed the principle as follows:—1st. A certain or sleeping rent, in proportion to the extent of coal leased or promised to be leased, and regulated accordingly from time to time. 2nd. A tonnage rent (Redevance,) is fixed annually by government, which is levied, not exceeding

5 per cent., upon the net produce of the mine; the mode of taking such amount is regulated by an imperial decree of the 6th of May, 1811.

The tonnage rent subsequent to the year 1823 had been fixed at 2½ per cent. upon the saleable produce.

In 1828, the Mons district averaged 13,800 tons per annum, equal to 46 tons per day for each pit.

In 1838, in the same District, there were 97 steam engines for drawing coals, and 38 for raising water, with 178 working and sinking pits.

In 1828, Liege had 103 pits, raised 570,084 tons of coals, and employed 9267 workmen.

In the same district, in 1838, the number of men employed were 7580, women 1451, boys 1617, making a total of 10,648, with an average daily wage of 1f. 85c., producing 740,408 tons of coals.

The quantity of coals raised in Hainault, by 25,244 colliers, was 2,415,910 tons, the *bona fide* value of which was 10,315,082 francs.

VENTILATION.

Much has been written on the subject of ventilation by the Belgian engineers. M. Boisse says:—In the most extensive mine which he had visited, the current consisted of 8 cubic metres per second, and the current was subdivided into five branches, all of which were united before ascending the upcast pit. The greatest speed he ever saw, was 1·20 metres per second. When the speed is 1·50, it will extinguish naked lamps.

In many cases, no artificial means are used to propel the ventilating current; sometimes a water-fall is employed, and also air pumps; generally lamps or furnaces of various descriptions; but the centrifugal ventilating machine was held in the highest repute at this period (1838).

They sometimes employ a portable machine of the same description, capable of producing a volume of one-half a cubic metre per second.

The first air-pump was erected in 1830, in the district of Mons, at the Pit St. Louis, in the concession of Grieseuil. The most powerful is that of l'Espérance, near to Seraing, which extracts 8 cubic metres of air per second.

In the coal mines near Valenciennes, the furnace air is taken down the ladder pits, and the quantity necessary for the furnace, is regulated by double doors; the hot air escaping by the main pit, at 15 or 20 yards distance.

Mons. Gonot, another eminent engineer, has also performed a great

many experiments relative to the principles of ventilation, and published a course of experiments made from 45 different hypotheses, the result of which led him to the following conclusions :—

1. *Temperature*—The *increased* temperature of the upcast to that of the downcast air in most cases was 20 deg.; in some instances it was 35; and in one particular case it was 60 deg.; the furnace being placed in the upper part of the shaft, the depths ranging from 200 to 300 metres.*

2. The length of air course averaged about 2,000 metres per single column.

3. The mean section of air-course 2·80 by 1·90 equal 5½ square metres.

4. Mean speed of column 1·3 per second, the greatest speed 1·54, with an air-course 14 by 4·2 equal 17·96 cubic metres per second. The least *volume* was 1½, and the greatest was 20 cubic metres per second, the average ranging from 8 to 15 cubic metres per second. At the greatest speed, the interior current was several times subdivided; and it is a very proper arrangement in the Belgian collieries to enlarge the main outlet, embracing the junction of all the columns equal to the upcast shaft.

Mons. Gonot first lays down certain practical data, and then reasons and calculates the results of certain alterations, founded upon acknowledged or ascertained principles. But as these details are foreign to my present purpose, I will not pursue the subject further than to remark that the volume of air resulting from these several statements varies from 3 cubic metres per second to 20, and taking the mean volume of the improved air courses by means of several divisions, at 15 cubic metres per second, is equal to 24,500 cubic feet per minute, which is very inferior to the well ventilated pits in England; especially when the excessive proportion of shafts in Belgium is taken into consideration, together with the limited extent of the air courses, which scarcely ever exceed 2,000 metres in length, the speed of the air being about 4 feet per second.

Notwithstanding the great and laudable pains taken by the government in the education of mining engineers, and the literary and scientific acquirements exhibited by many of them in the publication of the different essays on the prevention of accidents in the mines, I am free to confess that the result of my observations is that a great deficiency exists in respect to safe and economical measures for carrying on these coal mines, especially in the deep mines which I saw.

* As he takes the temperature of the air at top of the upcast pit, it is of course influenced by the degree of heat from the furnace below.

I have been induced to go more into detail upon the mode of working the mines since I perused an extract from a report made by Mons. Briavionne, engineer in chief of the mines of the Borinage, in the basin of Charleroi, who predicted (in 1839) "That, at the end of 20 years, the coal mines of western Belgium would have arrived at the last stage of profitable working." He says, "That the mean deepening of the pits has of late years progressed at the rate of 15 metres per annum, and, at the present moment, the works have attained a mean depth of 247 metres (134 fathoms) in the district west of Mons, and 147 metres (80 fathoms) in those of the centre and of Charleroi."

"Supposing that these workings be so equalised as to reach altogether to the depth which they would seem not destined to exceed, that is 500 metres (= 268 fathoms), they would, before 20 years, have arrived at this stage every where; and the coal (assuming it to exist in abundance beyond this limit) would be so costly and difficult of extraction, and so expensive, as to take it out of the reach of the common uses of the day."

This announcement came with appalling force upon the numerous joint stock companies which were established in 1836—7, when people thought themselves fortunate if they could only obtain a share in these concerns, at ever so exorbitant a rate.

According to Mons. Briavionne, in his work "*De l'Industrie en Belgique*," we find that three-fourths of the total quantity are raised in the three basins around Mons, the centre, and Charleroi, the remaining quarter in Liege and Limburgh.

The capital of the different companies was stated at 40,540,000 francs, from 1833 to 1838 inclusive, = £1,620,600.

I will now advert to the report of M. Em Van Horebeke, to the Government, published 20th Dec., 1854, being a review of the progress of coal mining and its results from the year 1841 to 1850, inclusive; dwelling especially upon the arrangements, powers, and results, in the latter year. The whole of these statements being confirmed by the official tables.

It appears that 138 new concessions were granted during the above 10 years.

In 1850—There were Working Pits	408	
In Reserve	159	
		567
In course of Sinking		25
Total		592

During the said 10 years the number of working pits had considerably

fallen off although the quantity raised had greatly increased, which is attributable to the introduction of cage guides (as a substitute for the cuffats) and other improvements.

The mines of Hainault, being the most deep and important, stand foremost in the march of improvement.

The employment of steam engines with horizontal cylinders has also reduced considerably the cost of the coals. In 1850, they averaged 30 horse-power each, whilst in 1841, they only averaged 26.

The number and horse-power of the steam engines for winding coals in 1841 and 1850 were as follow:—

	No.		Horse-power.
In 1841.....	318	average	8,587
„ 1850.....	384	do.	11,548

The number and horse-power of pumping engines in 1841 and 1850 were as follow:—

	No.		Horse-power.
In 1841.....	102	average	10,079
„ 1850.....	143	do.	16,081

The employment of steam engines for the ventilation of mines, and in the working of air-pumps or spirals, remained stationary up to 1848 and 1849, but took a marked extension in 1850, 14 applications, with an average power of 15 horses, having been added in that year.

In 1841	No. of Engines	15	aggregate horse-power		159
„ 1850	do.	78	do.	....	777

The wages of the workmen in 1849 were 1·50f., but in 1850 they rose to 1·55f., the number of people employed being

In 1841	37,629
„ 1850	47,949

The corresponding quantities of tons of coal raised were,—

In 1841.....	4,027,765 tons
„ 1850.....	5,820,588 „

The following table embraces the general statistics of the trade in 1850, viz.:—The number of collieries, with those inactive; the number of pits working, and in reserve; the number of winding engines by horse and by steam, those also used for ventilation and for pumping water; also, the number of men, boys, women, girls, and horses employed above and below ground.

GENERAL STATISTICS OF COAL MINES IN 1850.

	No. of Collieries.		Pits in Work.	Pits not Working.	Winding Steam Engines	Winding Horse Eng.	Pumping Engines.	Ventilation	Men and Boys.		Women & Girls		Horses	
	In Work.	Not Work.							Below Ground	Above Ground	Below Ground	Above Ground	Below Ground	Above Ground
Hainault comprises, Mons, centre, & Charleroi ...	104	49	244	94	283	51	89	66	23483	6320	3149	1856	222	603
Namur	28	12	67	44	15	54	6	..	979	282	16	59	7	3
Luxemburg	1	..	1	..	....	1	....	..	18	....	....	....	..	..
Liege	74	41	96	46	86	25	48	12	8455	1994	330	998	151	153
Totals	207	102	408	184				78	32935	8606	3495	2913	380	759
									8606		2913			
			Engines		384	131	143		41541		6408			
			Horse-power ..		11548	327	16081				41541			
											47949			

	Horse Power.	Engine Power.
Hainault	51	98
Namur	54	105
Luxemburg.. } ..... Liege..... }	26	123
	131	326

GOVERNMENT ROYALTY RENTS, 1856.

	Fixed. Francs.	Proportional Francs.
Hainault	8,729	103,038
Namur	1,205	5,477
Luxemburg	13	3
Liege	3,169	22,857
Total	13,116	129,575

It is remarkable, amidst such an extraordinary number of seams of coal which this district contains, that they are nearly all under a metre in thickness. The Fallisole Colliery, St. Ann Seam, in Namur, is 2 metres; and Le Chateu Vein du Chateu has a seam 2·50; but the most of the working seams are only 2 feet thick.

In the following table is shown the proportional produce in Round Coals, Gailettes, and other sorts, Gailetterie and Menu (small), also the aggregate cost of labour and other charges, with the selling price. It

will be seen that whilst 123 collieries have gained 7,317,429 francs, 84 have lost 1,156,652f., whilst 3,681,945f. have been expended in preparatory works.

PRODUCE IN 1850, WITH VALUE AND EXPENCE OF RAISING.

	Large Gallettes	Other Forts.	Total.	Workmen. Labour.	Other Charges.	Charge.	Value.
				Francs.	Francs.	Francs.	Francs.
Hainault	382738	4038023	4420761	16608796	14567703	31176499	36757379
Namur	1806	175700	177506	502755	265969	768724	913577
Luxemburg	....	296	296	2809	700	3509	2513
Liege	43655	1178570	1222225	5124294	3237593	8361887	8817924
Total	428199	5392589	5820788	22258654	18071965	40310619	46471393

	Francs.	Cents.
The highest price of Large Coals (Long Flamme), in 1850, was	19	17
Middling Sort ..... „	11	10
Small ..... „	5	0

The annexed table exhibits the progressive quantity of tons raised in each of the districts by each 100 workmen, viz., that in the centre 100 colliers raised, in 1841, 12,960 tons; whilst, in 1850, they raised 14,940 tons, although the collieries were becoming deeper and more extended, but which disadvantages would appear to have been over-balanced by the improvements which had taken place.

QUANTITY OF TONS RAISED BY 100 WORKMEN IN EACH DISTRICT.

	1841	1842	1843	1844	1845	1846	1847	1848	1849	1850
Mons	10297	9630	8942	10420	12200	11000	11100	10808	10500	10751
Centre	12960	12739	12952	13636	12880	12045	13320	11730	12333	14940
Charleroi	12963	12614	13058	14323	14375	13875	14400	13329	14033	15457
Namur	10231	11793	13689	12181	13500	12308	12153	13083	13123	13640
Luxemburg	2900	5453	4750	4500	7530	6330	7070	4727	4609	1287
Huy	3935	4708	5200	6351	6292	5400	5000	7190	8604	7339
Liege	9682	9200	10573	10709	10019	9000	9761	8450	9300	10517
Average....	10712	10355	10526	11548	11884	11200	11551	10806	11420	12152

The ratios of production during the ten years, in comparison with the number of collieries, were as follows:—

	Increased Production. Per Cent.	Increased No. of Workmen. Per Cent.
Mons	30	46
Centre	67	46
Charleroi	72	42
Namur	45	15
Liege	32	21
Huy	5	50

The total general vend in 1850 was 5,820,788 tons.

The number of fatal accidents attributable to each 1000 workmen, including shafts, falls, explosions, &c., as also the population employed above and below ground, and the difference between fiery mines and mines non-fiery in 1850, are shown in the following Table :—

	Shafts, Ropes, and Chains.		Ladders.		Falls.		Explosions.		Water	Sundries.		Total.	
	Wou.	Dths.	Wou.	Killd.	Wou.	Killd.	Wou.	Killd.		Wou.	Killd.	Acc.	Dths
Hainault	13	30	1	2	21	32	6	83	....	18	13	59	160
Namur	1	3	..	..	3	2	..	..	....	3	1	7	6
Luxemburg	..	..	..	..	1	..	..	..	....	..	..	1	..
Liege	5	14	..	1	7	16	..	..	....	3	16	15	47
Total	19	47	1	3	32	50	6	83	....	24	30	82	213

Hainault, comprises Mons, Centre, both Banks of the Meuse, and Charleroi.

	Above ground.	Below ground.
Population employed during same period, viz., Men and Boys	8,606	32,935
Women and Girls	2,913	3,495
	11,519	36,430
		11,519
Making a total of		47,949

The rate of accidents in collieries in 1850, was, in every 1,000 workmen, 3·2 wounded, 1·5 killed.

Particularized for every 1,000 *Workmen.*

	Fiery Mines.	Non-fiery Mines.	General.
Hainault	8·71	3·62	6·16
Namur and Luxemburg	3·79	3·79	3·79
Liege	4·25	4·14	4·21

Up to the end of 1850, very little progress had been made with cages, for it is remarked that the increased use of ropes and baskets (instead of ladders) had added to the fatalities, but improvements in the machinery were progressing.

SUMMARY OF TABLES AND EXTRACTS SHOWING THE PROGRESS FROM 1838 TO 1850 INCLUSIVE.

	1838.		1841.		1850	
	No.	Horse Power.	No.	Horse Power.	No.	Horse Power.
Pits in activity	480	....	470	....	408	....
Suspended or in preparation	172	....	110	....	184	....
Total	652	....	580	....	592	....
Winding Engines	211	4969	318	8587	384	11548
Pumping Do.	90	8441	102	10079	143	16081
For Ventilation	7	102	15	159	78	776
Total	308	13512	435	18825	605	23405

	1838.	1841.	1850.
Workmen and Boys	37,171	37,629	41,541
Women and Girls	—	—	6,408
			47,949*
Tons of Coal raised	3,260,271	4,027,765	5,820,588
Horse Machines	—	—	131 engs.—327 h.p.
Horses below ground	—	—	380
Do. above Do.	—	—	759
Average Tons raised by each 100 Colliers	8771	10,712	12,152
Do. Do. by each Pit	6792	8756	14,266
Do. Wages of Workpeople.	1·45	1·50	1·55
Coals exported	1,198,300	—	1,987,186
Do. Home Consumption	2,061,971	—	3,833,398
Total	3,260,271		5,820,584

Highest price of large coals .. 23f.
Deepest pit ..... 510 Metres. Mariemont 560
Fatal accidents for every 1000 Workmen..... 3·4

	Below Ground.	Above Ground.	
*Men and Boys	32,935	8,606	41,541
Women and Girls	3,495	2,913	6,408
	36,430	11,519	47,949

Before quitting this portion of the subject, I am bound to acknowledge that the extreme thinness of the coal seams, and the great depth at which many of the mines lie, bear heavily against the economic working, and, although the wages of the workmen are found to be so very much lower than those of England, yet the state of mining, and the control of Government, combine to counteract the full effect of the said low wages, so that with the very fullest introduction of improved working I question much that Belgium can be expected successfully to compete with England if the French import duties were struck off, especially as the cost of transit from Durham and Northumberland may be expected to be done as cheaply to Paris by sea as from Belgium by means of canals and railways.

Comparison of some of the leading facts between the coal mining of Belgium and the counties of Durham, Northumberland, &c.:—

Belgian Collieries, 1850.

	Below Ground.	Average Wages.	Above Ground.	Average Wages.
Men	28471	1·72	7531	1·74
Boys	4464	0·94	1075	·65
Women	2274	1·30	1771	·92
Girls	1221	·85	1142	·56
	36430		11519	
Total			47949	

Produce of Coals, 1850.

No.	Hard Picked.	Other Sorts.	Total.
1 Burning almost without flame	5,632	515,506	521,138
2 Short flame	53,288	379,104	432,392
3 Long flamme Houille Maigre.	173,261	1,252,249	1,425,510
4 Do. Houille Grasse	159,373	2,009,838	2,169,211
5 Do. Houitte Grasse	36,645	1,235,692	1,272,337
	428,199	5,392,389	5,820,588

Durham and Northumberland, 1854.—*The persons employed may be stated at,*

Below ground	28,100
Above ground	10,701
Total	38,801

In 1828, the number of collieries were 59, in 1846 129.

The power of pumping engines in 1846 was 10,919
„ Winding engines..... 8,285
Capable of raising 57,718 tons daily, or 15,000,000 tons per annum, of 260 working days.

According to Mr. Hunt's late statistics for 1854, the coals raised in the counties of Durham and Northumberland, were:—

	Tons.
Exported.....	2,433,184
Coals converted into coke	1,325,052
Do. sent coastwise by sea and railway to Ireland	7,762,379
Do. consumed in iron-works, 52 furnaces	1,200,000
Do. colliery consumption	1,100,000
Local consumption and manufactures	1,400,000
	15,220,615

The above extracts exhibit some remarkable facts as bearing upon the economic working of the mines, viz.:—

	Belgium.	Durham and Northumberland.
Taking the whole of the hands employed above and below ground, the produce in tons, per annum, attributable to each person, is shown in each country to be	112	397
Ditto, persons exclusively employed underground	148	548

This speaks volumes regarding the powers of the English collieries. Undoubtedly much is attributable, as before remarked, to the general thickness of the seams and the extensive application of machinery *above* and below ground.

I select from the records the following regarding the respective depths of the chief collieries in Belgium, and find that in 1850,

That 47	pits range from	300 to 350	Metres.
26	ditto	350 to 400	„
27	ditto	400 to 450	„
3	ditto	450 to 500	„
4	ditto	500 to 560	„

The deepest colliery is at Mariemont, Hainault, it works 12 seams, averaging 56 metres in thickness; only one seam, Dupark, being a metre in thickness. At that colliery they have 11 working pits, each with a steam engine for winding, aggregate horse-power 400, average 36; and 3 pumping engines, whose aggregate power is 535 horses, averaging 178 horse-power. All these mines are ventilated by furnaces.

In 1854, Mr. Dickinson, the Government Inspector, read some statistics to the Philosophical Society of Manchester, with the design of showing that the fatal accidents in Belgium were less than those of the English collieries in his district, viz., Lancashire, Cheshire, and North Wales:—

	Tons.
Lancashire, yearly produce	8,255,000
Cheshire	715,000
North Wales	953,000
Total	9,923,000
Persons employed below ground	31,950
Ditto above ground	6,850
Total	38,800

	Tons.
According to this he makes every 100 persons to produce	25,600
Taking the under-ground persons only to produce	31,000

"With reference to the subject of fatal accidents in mines, he states them at 215 upon 38,800 persons employed, = $5\frac{33}{100}$ deaths for every 1000 workpeople, which, he says, is truly alarming; for in the Belgian mines the loss of life during five years, ending 1849, averaged only $3\frac{14}{100}$ per 1000, and one life lost for every 34,911 tons of coal raised; and in 1851-2, when accidents were more rife, it only amounted to $4\frac{5}{100}$, being, in both cases, less than the per centage of his district."

Now, the Belgian deaths in 1850 were 212 upon 5,820,588 tons, = 27,125 tons for each death, whereas in the three above counties 215 deaths upon 46,153 tons for each death, is 41 per cent. less in proportion than that of Belgium, and it is submitted that the tons of coal raised is a much fairer principle to take than the number of persons employed, and taking Mr. Dickinson's district to raise 9,223,000 tons, and to have 215 deaths, gives one death for every 46,153 tons of coal. Mr. Dickinson's district has 423 collieries, but 879 working pits for 9,923,000 tons = 11,402 tons per pit, per annum. Several of these shafts are working coals 600 yards below the surface.

In 1854, the respective produce of coals for every 100 workpeople was:—

		Tons.	Tons.	People.
Belgium	47,947 persons produced	5,820,588	= 12,151	per 100
Belgium	36,430 do. below ground produced	5,820,588	= 15,915	ditto.
Durham and Northumb.	38,801 persons produced	15,420,615	= 39,744	ditto.
Durham and Northumb.	28,100 persons produced	15,420,615	= 54,870	ditto.

In Belgium, the proportion of people employed *above ground* = ·24, one-fourth of whom are women and girls. In England = ·27, no women being employed.

There appears a great disparity in the number of tons of coals raised by each colliery. According to Mr. Hunt's Geological Survey for the year 1855, the produce of each colliery is shown, but not the number of pits belonging to each, viz. :—

	No. of Collieries.	Tons Produced.	Tons per Colliery.
Durham and Northumberland	273	15,431,400	56,525
Yorkshire	333	7,747,470	23,265
Warwickshire	17	262,000	15,410
Leicestershire	11	425,000	38,633
Staffordshire and Worcestershire	500	7,323,000	14,646
Lancashire	357	8,950,000	25,000
Cheshire	32	755,500	23,600
Shropshire	56	1,105,250	19,736
Gloucestershire, Somersetshire, and Devonshire	86	1,430,620	16,635
North Wales	65	1,125,000	17,300
South Wales	245	8,550,270	34,900
Scotland	403	7,325,000	18,175

In Belgium 408 pits have only produced 5,820,588 tons = 14,266 per colliery.

Proportion of Fatal Accidents.

The fatal accidents in Belgium upon each 1000 workmen in 1850, were :—

In Fiery Mines ..... 7·12 per 1000
Non-Fiery Mines ..... 3·79 „ } average 5·4

There were 5,820,588 tons of coal raised, and 212 persons killed, equal one death for every 27,125 tons raised.

In Durham and Northumberland 114 persons were killed in 1854, the quantity of coal raised being 15,420,615 tons, giving only one death for every 135,260 tons, showing the mortality in Belgium to be *five times* the ratio of these counties, notwithstanding the Government legislation, and that the deepest collieries do not exceed 250 fathoms. It is to be regretted that in these statistics we have no means of ascertaining the number of hewers in each district.

Having, in the previous pages, endeavoured to show, notwithstanding the high price of coals and increased demand both in Belgium and France, that the produce of the mines has very imperfectly responded to such demand, I consider it but just to state wherein I conceive the chief deficiency to rest, and I will take leave to suggest the only remedial

course to be adopted for extensively working the deep mines, and thereby to save the country from an impending crisis, at the same time, I am not unaware of the difficulty of carrying such into effect.

1. The fittings up of the Belgian collieries with respect to the size of the shafts, the power of the steam machinery, and the very inadequate manner of conducting the men and the coals to the surface by means of ladders, are not well calculated for deep working, which must necessarily command large quantities to effect economic working.

2. The shafts are not amply secured nor calculated for effective furnace ventilation, without which the increasing high temperature cannot be adequately carried off by ventilation, especially as the air current must necessarily be subdivided into several seams or channels which, in the opinion of Mons. Briavionne, would of itself put a limit to the deep working beyond 260 fathoms.

3. The unimproved mode of handling the coals after being landed at the surface is productive of vast unnecessary labour, and is ill suited to the separation of the different parts for the respective markets.

4. The mode of working the mines I will not touch upon, as they vary so much in declivity, thickness of seams, &c., that no general rule can be applied; at the same time, judging from what I saw in 1843, I am of opinion that great improvement is practicable.

Having thus taken the liberty of remarking upon many of the deficiencies of the Belgian arrangements, I think it is but just that I should suggest some general principles for commanding a proportion of the numerous seams of coal lying below the depths at present attained, that is, the scale of establishment necessary to compass this object.

1. Two or more spacious shafts, a pumping engine of from 150 to 200 horse-power, also two winding engines of, at least, 80 to 100 horse-power each, a distinct proportion of shaft being allotted to the ventilating furnace, the said shaft to be lined with stone or fire brick.

2. The winding shafts to be fitted up with guides for cages, such cages to contain two, three, or four tubs each, after the manner of the deep collieries in the North of England. This apparatus will necessarily supersede the use of ladder pits, which, in itself, will constitute an immense advantage.

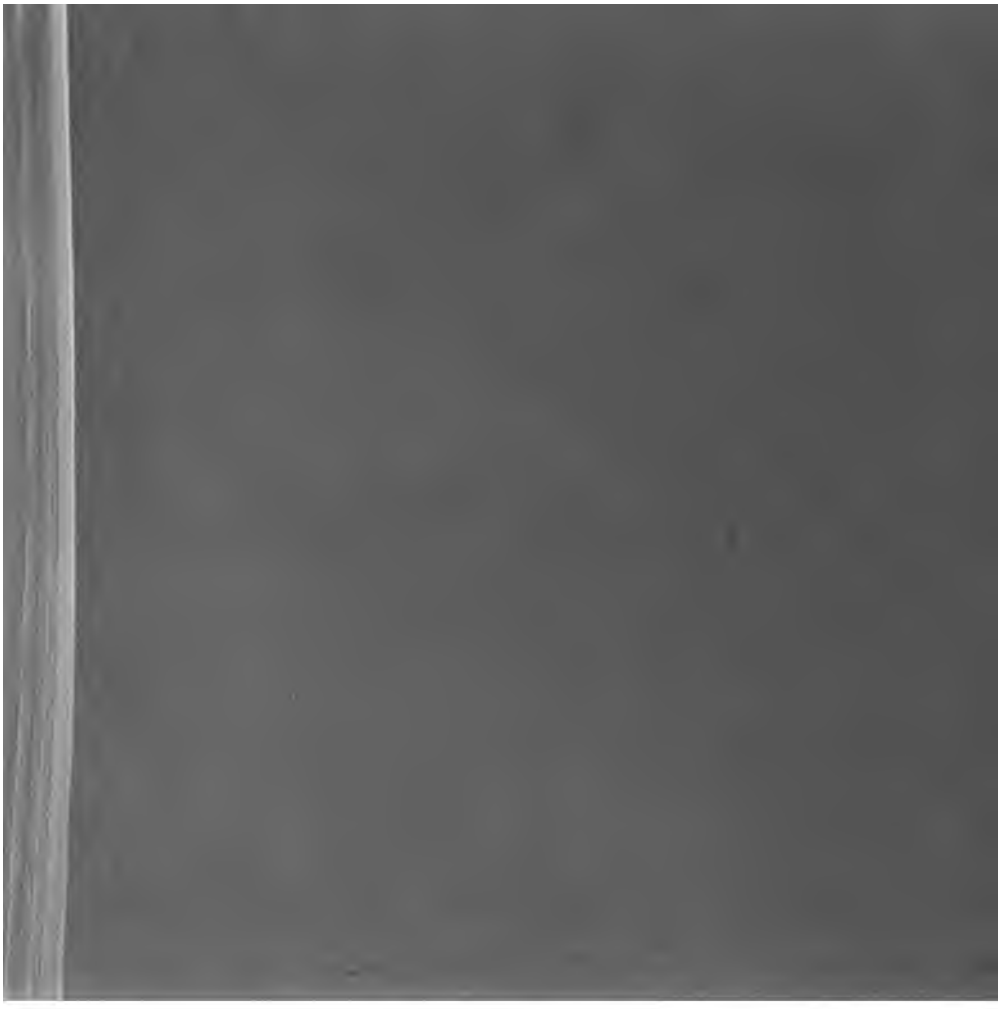
3. The water met with in the shafts, according to modern practice, should be tubbed back with cast-iron segments, and, to provide against corrosion or decay, the said tubbing should be guarded by fire bricks in the upcast shaft.

4. As this description of establishment is calculated to bring the coals from great distances, the roads should be laid out upon the principle of six feet in height, and guarded by pillars of adequate strength proportioned to the depth from the surface, the strength of the coal and the hardness of the floor.

5. The ventilating furnace must be spacious, placed at a convenient distance from the shaft, and well guarded from firing the coal by arching; a separate air-way, or dumb drift, should also be arranged for passing any portion of the air into the shaft, which may become inflammable without coming in contact with the flame of the furnace.

6. A colliery fitted up as above with two winding engines, if properly supplied with coal from below, will raise from 1000 to 1200 tons of coal per day.

7. A very necessary appendage to the above is an extensive suite of screens, to separate the coals into first, second, and third qualities, according to modern improvements, without which no great colliery can be advantageously carried on, for it is greatly attributable to this want that the proportion of large coals in Belgium is so inconsiderable.

8. The application of engines for hauling the coals below ground is also a very necessary constituent for the prosecution of extensive workings.

I will conclude with remarking that, as the concessions are so intermixed in each colliery, it might be necessary, in order to carry out many of these suggestions, that the aid of the Government should be extended; but, as the subject is of such vital importance to the country, it is highly probable that this exposition may induce the attention of the leading engineers, and although these remarks may be found in many respects incorrect, and in sundry cases anticipated, I hope the effort will be set down to a desire of arriving at the truth.